3.2 Outcomes

This section describes the safety and health accomplishments over the past ten years for each strategic goal of the Mining Research Plan. The section begins with a list of the seven strategic goals and strategic program outcomes produced through implementation of the research results for each goal. Listed within each goal are intermediate outcomes that support the strategic program outcomes. For each intermediate outcome, there is a brief description of the problem, research and development activities, R&D outputs and transfer activities, a description of the intermediate outcome, and a list of past outputs which contributed to the intermediate outcome.

Strategic Goals	Strategic Program Outcomes
1. **Respiratory diseases -** Reduce respiratory diseases in miners by reducing health hazards in the workplace associated with coal worker pneumoconiosis, silicosis, and diesel emissions.	▸ Reducing Coal Dust Exposures Through Improved Monitoring and Control ▸ Reducing Silica Exposures in Mining Through Improved Control Technologies ▸ Reducing Exposures to Diesel Emissions Through Improved Monitoring and Control
2. **Hearing loss -** Reduce noise-induced hearing loss (NIHL) in the mining industry.	▸ Preventing Noise-induced Hearing Loss
3. **Cumulative injuries -** Reduce repetitive/cumulative musculoskeletal injuries in mine workers.	▸ Preventing Musculoskeletal Disorders
4. **Traumatic injuries -** Reduce traumatic injuries in the mining workplace.	▸ Reducing Traumatic Injuries and Fatalities in Blasting ▸ Reducing Electrically Related Traumatic Injuries ▸ Reducing Machine-related Traumatic Injuries
5. **Mine disasters -** Reduce the risk of mine disasters (fires, explosions, and inundations); and minimize the risk to, and enhance the effectiveness of, emergency responders.	▸ Preventing and Mitigating Mine Fires and Explosions
6. **Ground control -** Reduce ground failure fatalities and injuries in the mining industry.	▸ Reducing Fatalities and Injuries Due to Ground Failures
7. **Surveillance and training -** Determine the impact of changing mining conditions, new and emerging technologies, training, and the changing patterns of work on worker health and safety.	▸ Improved Training Materials and Methods to Prevent Injuries and Illnesses ▸ Reducing the Hazards of Mining's Emerging Issues

Strategic Program Outcome for Respiratory Diseases

Reducing Coal Dust Exposures Through Improved Monitoring and Control

Long-term exposure to excessive levels of respirable coal mine dust can lead to coal workers´ pneumoconiosis (CWP), a debilitating lung disease commonly known as "black lung." The last 35 years have seen major gains in the national effort to reduce CWP. The percentage of dust samples exceeding the 2 mg/m3 federal regulatory limit for continuous miner workers has dropped from 49% to 9%. For longwall workers, the percentage has dropped from 44% to 12%. Likewise, the prevalence of CWP category 1/0+ or higher has dropped from 28% to 8%.

These improvements are due in great part to the development of new dust control technology by NIOSH. Of course, new technology was not the only cause for these improvements. Strong enforcement by the Mine Safety and Health Administration (MSHA) and changing attitudes within the coal industry were vital. Nevertheless, NIOSH made a critical and essential contribution by providing the engineering control tools to make these improvements possible.

Our research has resulted in dozens of new and practical ways to control dust that are now used every day in the coal industry throughout the United States. For example, research for longwalls has identified optimum spray types and locations in cutting drums, developed directional spray systems for the longwall shearer, identified optimum operating pressures for different water spray types, demonstrated methods to control dust from crusher/stageloader units, and improved operating practices such as worker positioning and cutting practices.

MSHA has played a valuable role in promoting NIOSH-developed technology. For instance, in 1999, MSHA placed a Longwall Dust Control Toolbox on its website to guide longwall operators in their efforts to control respirable dust. Most of the control technologies shown in this toolbox were developed by NIOSH, with 28 of the 32 cited publications reporting on our research findings.

At the same time that new techniques were being developed to reduce dust, countertrends within the industry were underway. Production levels on both continuous miner and longwall sections were undergoing huge increases. Compared to 1971 levels, the 2003 shift production at continuous sections more than doubled. Longwall production increased nearly tenfold. Higher production means more dust. Nevertheless, the new dust controls being introduced were so numerous and so effective that compliance with federal dust standards continued to improve.

Although significant reductions in average worker overexposures and CWP have been achieved, shift production levels continue to increase. Thus, the task of protecting miners from respirable coal dust is far from finished. For example, today the highest production continuous miner sections are producing over 2,000 tons per shift, while the highest production longwalls routinely produce over 15,000 tons per shift. This represents about 2.5 times the average for the industry. Further improvements in control technologies are still needed, particularly for a number of high-risk occupations.

In recent years, NIOSH has developed dust control technologies that build on or supplement the controls already being used. For example, continuous miner research showed that blocking sprays, if properly used, can reduce dust levels at the operator locations. Blocking sprays create a water barrier near the cutting face, which prevents dust from rolling back to the operator locations at the

back of the machine and allows the dust to be captured by the scrubber inlets. A major continuous miner manufacturer now offers blocking sprays on its machines, and new continuous mining machines are underground with these sprays installed. NIOSH researchers also found that thinner filters were being used in flooded-bed scrubbers on continuous miners. Research showed that these thinner filters allowed 30% more dust back into the mine air. NIOSH recommended the use of thicker filters in a NIOSH *Hazard ID* flyer. MSHA requested 1,000 copies of this *Hazard ID* to distribute to mine inspectors as part of its initiative to lower silica dust exposure. MSHA has also required mine operators to use these thicker filters when dust problems exist and currently requires the industry to specifically identify these filters in dust control and ventilation plans.

In 2003, all of the dust control technologies that we developed over the years and that are currently in use in mines were published in a handbook. This handbook provides a single information source to help mine operators control dust levels. To date, this handbook has had wide acceptance based on requests and feedback from industry, labor, and regulatory agencies. The handbook is also available on the NIOSH Mining Website.

In addition to major research directed at coal dust control technology, a parallel research effort devoted to improved dust sampling has been ongoing for the past 10 years. Under the Federal Coal Mine Health and Safety Act of 1969, personal gravimetric dust samplers were specified as the instrumentation to be used to monitor compliance with federal dust regulations. These samplers use a size-selective cyclone to collect the respirable fraction of dust on a filter. The mass of dust, pump flow rate, and sampling time are used to calculate an average dust concentration for the shift. This concentration is not determined until the filter has been weighed at MSHA´s Pittsburgh lab several days after the sample is collected. This sampling process has not changed in the past 36 years. In 1999, NIOSH began developing a mass-based, continuous dust monitor that could be worn as a personal dust sampler. This personal dust monitor (PDM), built into the miner´s cap lamp system, provides a running average of dust exposure at any point in the shift, projects an end-of-shift concentration, and provides an actual end-of-shift concentration without any delay. This information will allow mine operators and workers to monitor the dust exposure during the shift. It will empower workers to make changes if it seems that their shift exposure will exceed the standard. The PDM is currently near the end of an extensive field evaluation to assess sampling accuracy, mine worthiness, reliability, and acceptance by mine workers. Results to date are very positive. The PDM is now commercially available.

In 2003, MSHA published proposed changes to its dust sampling program. In these new regulations, MSHA allowed for the use of the continuous PDM. However, industry and labor indicated in public response forums that MSHA should delay rulemaking until the PDM could be further evaluated as a compliance-grade instrument. Both industry and labor envision the PDM as having the potential to become the cornerstone for a new sampling process. Based on stakeholder input, MSHA suspended work on the proposed regulations until additional information on PDM performance is available. A NIOSH report on the latest series of underground and lab evaluations of the PDM is expected to be completed by the end of 2005.

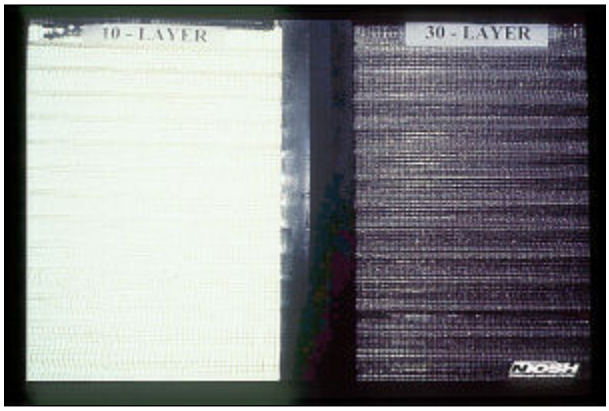
Intermediate Outcomes

- Effective Dust Collection with Flooded-Bed Scrubbers
- Handbook to Facilitate Transfer of Dust Control Technology for Mining
- New Personal Dust Monitor Empowers Miners to Reduce Their Dust Exposure
- NIOSH Establishes the Ineffectiveness of Area Dust Sampling as a Measure of Worker Exposure
- Reducing Miners' Dust Exposure Through the Use of Confining Sprays for Flooded-bed Scrubbers

Intermediate Outcome related to Reducing Coal Dust Exposures Through Improved Monitoring and Control

Effective Dust Collection with Flooded-Bed Scrubbers

Description of Problem



Difference in filter density using backlighting

NIOSH researchers found through a series of underground and lab investigations that flooded-bed scrubbers on continuous miners were not providing the level of respirable dust control (removal rates of about 90% or better) that earlier U.S. Bureau of Mines research had shown they were capable of providing. During this investigation in the mid-1990s, Pittsburgh Research Laboratory (PRL) researchers learned that equipment manufacturers were making thinner filters for the flooded-bed scrubbers in order to reduce filter back pressure. This extended the life of the filters and allowed for higher scrubber flow rates. This practice had gone unnoticed until recognized by NIOSH researchers while conducting other dust control research. It was immediately recognized that this change allowed more air to move through the scrubber with less resistance. However, there was no information on how this affected the efficiency of the scrubbers to collect respirable dust.

Research and Development Activities

PRL conducted a series of lab tests to compare the dust collection efficiencies of standard filters with those of the newer, thinner filters being supplied by manufacturers at that time. Results showed that, on average, the new thinner filters allowed 30% more respirable dust to be discharged by the scrubber back into the mine air. These new filters often had removal efficiencies of around 60%. Often, the discharge point of the scrubber is near to the continuous miner operator and the shuttle car operator. This results in an increase in dust exposure for these workers.

R&D Outputs and Transfer Activities

The results of this study were reported in a peer-reviewed journal and a conference presentation. The results were also reported in a NIOSH *Hazard ID* flyer, which was distributed to the industry. In 1997, the Mine Safety and Health Administration (MSHA) initiated a program to lower silica dust exposure and requested 1,000 copies of this *Hazard ID*. These were distributed to MSHA mine inspectors to increase their awareness of the issue. Inspectors were also asked to pass on this information to mine operators.

Description of Intermediate Outcome

As a result of these findings, MSHA has required mine operators to go back to the thicker filters when problems with silica control are encountered. MSHA also began requiring mine operators to specify the use of the thicker filters in their dust control and ventilation plans.

Greater awareness of scrubber performance and increased use of thicker filters has contributed to improved dust control in continuous miner operations and has reduced dust exposure at continuous miner faces.

Outputs

5 Outputs

Title	Year	Output Type	Strategic Goal
Laboratory Evaluation of Quartz Dust Capture of Irrigated-filter Collection Systems for Continuous Miners Colinet-JF; McClelland-JJ; Erhard-LA; Jankowski-RA | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 9313	1990	Publication	Respiratory diseases
NIOSH Hazard ID - Exposure to Silica Dust on Continuous Mining Operations Using Flooded-Bed Scrubbers Colinet-JF; Flesch-JP | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 97-147, 1997 Aug :1-2	1997	Publication	Respiratory diseases
Performance Evaluation of Irrigated Filters McClelland-JJ; Colinet-JF | Trans Soc Min Metal Explor, Vol 290. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :1828-1832	1992	Publication	Respiratory diseases
Respirable Dust Control Technology Utilised in Underground Coal Mines in the United States Colinet-JF | In: Proceedings of the Second International Underground Coal Conference, Hebblewhite BK, Galvin JM, Broome AJ, eds. , 1999; :171-179	1999	Publication	Respiratory diseases
Silica Collection Concerns When Using Flooded-Bed Scrubbers Colinet-JF; Jankowski-RA | Mining Engineering 52(4) 2000; :49-54	2000	Publication	Respiratory diseases

Intermediate Outcome related to Reducing Coal Dust Exposures Through Improved Monitoring and Control

Handbook to Facilitate Transfer of Dust Control Technology for Mining

Description of Problem

Over the last 30 years, much successful research has been done by NIOSH and the former U.S. Bureau of Mines (USBM) to reduce dust in mines. However, no comprehensive summary of practical dust control technology for mining industry personnel had been published. The information was available, but was scattered among a variety of publications. Therefore, it was hard to put together a comprehensive dust control plan for mines that addressed all required aspects of the plan.

The handbook is a comprehensive summary of practical dust control technology for all aspects of mining

Research and Development Activities

NIOSH used all of the available information from past NIOSH and USBM research and combined the information into a Handbook for Dust Control in Mining. This 131-page handbook describes methods for controlling mineral dusts in mines. Dust control methods are described for underground coal and hard-rock mines, as well as surface mines, stone mines, and hard-rock tunnels. The information is assembled in a way that is user-friendly and according to easy-to-find topics.

R&D Outputs and Transfer Activities

The handbook was published in June 2003. We have received hundreds of requests for the handbook by labor and industry organizations worldwide, and we have handed out the handbook at training sessions and conferences. We did several things to make the handbook "Web-friendly" in order to facilitate technology transfer:

- File size was minimized to make downloads faster.
- Text and figure size were maximized for easier reading on a computer screen.
- The text was single-column (rather than double-column) for easier reading on a computer screen.
- The Adobe Acrobat bookmark feature was used to produce an on-line index. This allows the reader to instantly move to any desired location in the document, instead of tediously scrolling through a large document.

The handbook is currently available on the NIOSH Mining Website.

Description of Intermediate Outcome

A key impact is that years of useful and practical dust control technology information is now consolidated into one easily usable format. Thus, the probability of its application in the mining industry is greatly enhanced. The handbook has been widely distributed within the U.S. mining industry. It has received positive notice from many foreign mining websites. Nevertheless, the main impact comes from the technology cited within the handbook. Most of the technology was developed by NIOSH or the USBM. It continues to have lasting impact on industry practice. Some of the major successes are:

- Shearer-clearer systems on longwall shearers.
- Spray nozzle application on continuous miners and longwall shearers.
- Deep cutting with dust scrubbers on continuous miners.
- Face curtains to control longwall ventilation.
- New sampling methods to find dust sources.
- New stopping construction methods for mine entries with a large cross-section.
- Improved dust control for surface drills.
- New methods for conveyor belt dust control.
- Dust control methods for hard-rock tunnels.

Outputs

25 Outputs

Title	Year	Output Type	Strategic Goal
An Evaluation of Three Wet Dust Control Techniques for Face Drills Page-SJ | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 8596. NTIS No. PB82-177320	1982	Publication	Respiratory diseases
An Update on Stageloader Dust Control Jayaraman-NI; Jankowski-RA; Organiscak-JA | In: Proceedings of Longwall USA (Pittsburgh, PA), 1992	1992	Publication	Respiratory diseases
Atomization of Water Sprays for Quartz Dust Control Jayaraman-NI; Jankowski-RA | Appl Ind Hyg 3; :327-331	1988	Publication	Respiratory diseases
Control of Respirable Dust by Improved Water Sprays Courtney-WG; Cheng-L | In: Respirable Dust Control - Proceedings of Technology Transfer Seminars, Pittsburgh, PA, and St. Louis, MO, US Bureau of Mines, Information Circular 8753, NTIS No PB 272 910; :92-108	1977	Publication	Respiratory diseases
Dust Sources and Controls on the Six U.S. Longwall Faces Having the Most Difficulty Complying with Dust Standards Jankowski-RA; Organiscak-JA | Pittsburgh, PA: U.S. Department of the Interior, Information Circular 8957. NTIS No. PB84-142058	1983	Publication	Respiratory diseases
Evaluation of a Combined Face Ventilation System Used with a Remotely Operated Mining Machine Divers-EF; Jayaraman-NI; Custer-J | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 8899. NTIS No. PB83-156794	1982	Publication	Respiratory diseases
Evaluation of a New Half-curtain Technique for Continuous Miner Faces Jayaraman-NI, Divers-EF, Derick-RL, Babbitt-C | In: Proceedings of the Symposium on Respirable Dust. University Park, PA: The Pennsylvania State University	1986	Publication	Respiratory diseases
Extended Advance of Continuous Miner Successfully Ventilated with a Scrubber in a Blowing Section Volkwein-JC; Thimons-ED; Halfinger-G | In: Proceedings of the Second U.S. Mine Ventilation Symposium (Reno, NV)	1985	Publication	Mine disasters
Factors Affecting Respirable Dust Generation from Longwall Roof Supports Organiscak-JA; Listak-JM; Jankowski-RA | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9019. NTIS No. PB85 236453	1985	Publication	Respiratory diseases
Field Assessment of Retrofitting Surface Coal Mine Equipment Cabs with Air Filtration Systems Organiscak-JA; Cecala-AB; Heitbrink-WA; Thimons-ED; Schnitz-M; Ahrenholtz-E | Proc 31st Annual Institute of Mining Health, Safety and Research, 2000, Aug 27-30 Virginia Polytechnic Institute and State University, Department of Mining and Minerals Engineering, 2000 Aug; :57-68	2000	Publication	Respiratory diseases
Foams for Dust Control Page-SJ; Volkwein-JC | Eng Min J 187(10):50-52, 54	1986	Publication	Respiratory diseases
Gas and Dust Control Kissell-FN | In: SME Mining Engineering Handbook. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc, 1992; :1004-1020	1992	Publication	Mine disasters; Respiratory diseases
Handbook for Dust Control in Mining NIOSH | NIOSH Pub No. 2003-147, IC 9465, 2003 Jun; :1-131	2003	Publication	Respiratory diseases

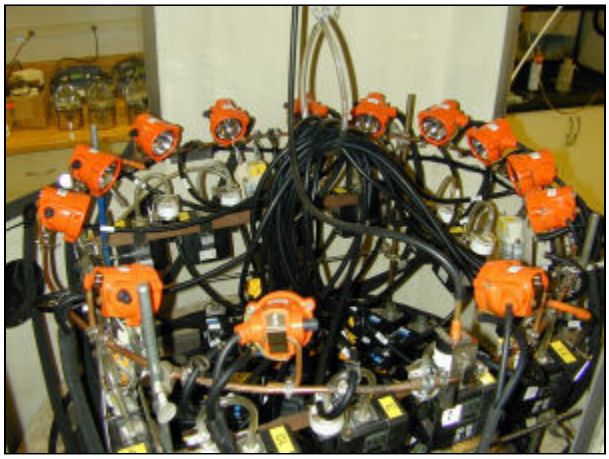
Title	Year	Output Type	Strategic Goal
How to Control Air Contaminants During Tunnel Construction Kissell-FN | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9439. NTIS stock number: PB96-147558, 1995	1995	Publication	All
Keystone Achieves Positive Dust Control During Dry Drilling Page-SJ; Folk-M | Eng Min J 185(9):84-85	1984	Publication	Respiratory diseases
Maintaining Filters, Bits Can Control Respirable Quartz Dust During Roof Drilling Divers-EF; Jankowski-RA | Coal Age, 1987 Feb; :57-59	1987	Publication	Respiratory diseases
Optimizing Continuous Miner Scrubbers for Dust Control in High Coal Seams Jayaraman-NI; Jankowski-RA; Whitehead-KL | In: Proceedings of New Technology in Mine Health and Safety Symposium. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc, 1992; :193-205	1992	Publication	Respiratory diseases
Silica Collection Concerns When Using Flooded-Bed Scrubbers Colinet-JF; Jankowski-RA | Mining Engineering 52(4) 2000; :49-54	2000	Publication	Respiratory diseases
Status of Dust Control Technology on U.S. Longwalls Colinet-JF; Spencer-ER; Jankowski-RA | In: Proceedings of the 6th International Mine Ventilation Congress, Ramani RV, ed., Chapter 55. Society for Mining, Metallurgy, and Exploration, Inc.: Littleton, CO, 1997; :345-351	1997	Publication	Respiratory diseases
Studies of Bit Wear and Respirable Dust Generation Organiscak-JA; Khair-AW; Ahmad-M | Trans Soc Min Eng, Vol. 298, Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :1874-1879	1996	Publication	Respiratory diseases
Technology news 118 - Lower Dust Exposure of Longwall Shearer Operator by Relocating the Machine Cooling Water Sprays USBM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Technology News 118, 1981	1981	Publication	Respiratory diseases
Technology news 203 - How to Reduce Shearer Operators Dust Exposure by Using Remote Control USBM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Technology News 203, 1984	1984	Publication	Respiratory diseases
Technology news 220 - How Twelve Continuous Miner Sections Keep Dust Levels at 0.5 mg/m3 or Less USBM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Technology News 220, 1985	1985	Publication	Respiratory diseases
Use of Foam for Dust Control in Minerals Processing Volkwein-JC; Cecala-AB; Thimons-ED | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 8808. NTIS No. PB84-131184	1983	Publication	Respiratory diseases
Water Infusion for Coal Mine Dust Control: Three Case Studies McClelland-JA; Organiscak-JA; Jankowski-RA; Pothini-BR | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 9096. NTIS No. PB88-120514	1987	Publication	Respiratory diseases

Intermediate Outcome related to Reducing Coal Dust Exposures Through Improved Monitoring and Control

New Personal Dust Monitor Empowers Miners to Reduce Their Dust Exposure

Description of Problem

In 1996, the Secretary of Labor asked NIOSH to develop a better dust monitoring instrument for coal mining. At that time, the coal mine "personal sampler" had been in use for 30 years. It is a rugged and reasonably accurate instrument. However, because the inside filter must be weighed in a lab, there was always a delay of a week or more in getting results back to the mine operator. The miners themselves seldom had any knowledge of their dust exposure. This delay meant that miners could be exposed to excessive dust levels without having the chance to immediately correct the problem and avoid overexposures for the entire shift.



Certification of PDM accuracy in the PRL Laboratory Marple Dust Chamber

Research and Development Activities

Initial work to develop a better dust monitoring instrument focused on a machine-mounted area-sampling monitor. However, NIOSH found that this area-sampling instrument was inadequate for compliance sampling of operator dust exposure. NIOSH findings showed that there was no consistent relationship between personal sampling equipment worn by workers and area samples. (See the Intermediate Outcome entitled "NIOSH Establishes the Ineffectiveness of Area Dust Sampling as a Measure of Worker Exposure.")

The work was then redirected to develop a monitor that was small and light enough to be worn by the workers (called a personal dust monitor, or PDM), but which kept most of the functionality features of the area monitor. One of the most important of these features was the ability to read out the gravimetric dust level during the work shift and to predict the full-shift dust level if nothing changed in the mining situation. This allowed workers and mine management to immediately correct engineering dust controls to remedy high dust levels, thereby avoiding overexposure of the workers. At the end of the shift, the PDM data are downloaded into a computer and stored for future reference. The concept was to empower miners and mine management to do something about possible dust overexposures in real time. The dust monitor was built into a miner's cap lamp unit so that miners are putting on their dust monitors when they put on their cap lamps. This makes the PDM more user-friendly for the miners.

R&D Outputs and Transfer Activities

The PDM has undergone a great deal of technology transfer. It has been discussed in numerous papers, presentations, and workshops, both national and international. It has been demonstrated at recent Mine Safety and Health Administration (MSHA) dust hearings. Mockups have been provided for industry and United Mine Workers of America meetings. International PDM partnerships have been established with Australia and the Republic of South Africa. The PDM was recently given an R&D100 award as one of the nation's top 100 technical developments of the year. A PDM Coal Partnership has been established with members from industry, labor, and NIOSH to promote the PDM and to exchange information on the technology.

Description of Intermediate Outcome

In March 2003, MSHA proposed new rules on how coal dust is to be measured. These proposed rules incorporated the new PDM instrument under development by NIOSH (Federal Register, Vol. 68, No. 4, pages 10805, 10807, 10809, 10826, 10827, 10874, 10875, and 10879). However, in 2003, the instrument had not been fully tested. Because of this and for other reasons, MSHA announced a postponement of the proposed dust rule (Federal Register, Vol. 68, No. 128, July 3, 2003, Proposed Rules, pages 39881-39882). Since then, additional underground testing of the latest version of the PDM has been ongoing. Findings have been highly encouraging.

The PDM is now available as a commercial product (http://www.rpco.com). Orders from mines to purchase the device have been received by the manufacturer.

Outputs

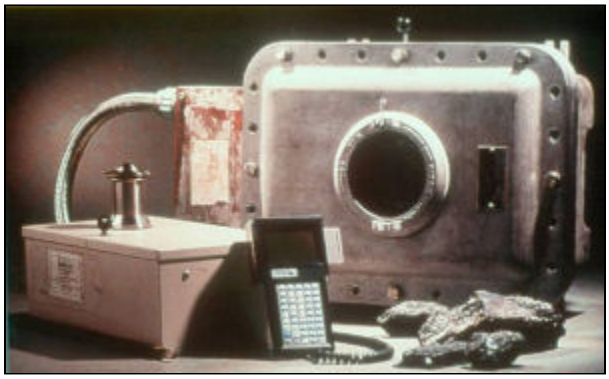
4 Outputs

Title	Year	Output Type	Strategic Goal
Analysis of Sampling Line Bias on Respirable Mass Measurement Peters-TM; Volkwein-JC | Appl Occup Environ Hyg 18(6); :458-465	2003	Publication	Respiratory diseases
Implementing a New Personal Dust Monitor as an Engineering Tool Volkwein-JC; Thimons-ED; Yanak-C; Dunham-D; Patashnick-H; Rupprecht-E | Coal Age 2004 Dec; 109(12):26-29	2004	Publication	Respiratory diseases
Performance of a New Personal Respirable Dust Monitor for Mine Use Volkwein-JC; Vinson-RP; McWilliams-LJ; Tuchman-DP; Mischler-SE | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2004-151, Report of Investigations 9663, 2004 Jun :1-25	2004	Publication	Respiratory diseases
State-of-the-Art in Monitoring Respirable Mine Aerosols Volkwein-JC; Thimons-ED; Timko-RJ; Hall-EE; Mischler-SE; Kissell-FN; Vinson-RP | In: Gillies ADS, ed. Proceedings of Eighth International Mine Ventilation Congress (Brisbane, Australia), AusIMM, Victoria, Australia, 2005; :151-156	2005	Publication	Respiratory diseases

Intermediate Outcome related to Reducing Coal Dust Exposures Through Improved Monitoring and Control

NIOSH Establishes the Ineffectiveness of Area Dust Sampling as a Measure of Worker Exposure

Description of Problem



NIOSH research showed area sampling was not indicative of worker dust exposures

In the mid-1980s, the Mine Safety and Health Administration (MSHA) initiated the development of a new kind of sampling instrument for measuring dust levels in coal mines - a machine-mounted respirable dust monitor (MMRDM). However, the MMRDM was more than a new sampling instrument. It also changed the location where samples are collected. The usual method of sampling for coal mine dust uses "personal sampling," i.e., equipment worn by the workers. The MMRDM, housed in a 160-pound box, had to be mounted in a fixed location. The general location being considered was on the mining equipment, such as fixed locations on continuous mining machines or on longwall shearers or longwall shields. Thus, it could only be used for sampling in a particular area. However, area sampling equipment does offer the benefits of providing more functionality and being less subject to possible tampering.

Developing the MMRDM was very controversial within the coal industry. The industry believed that it was likely to measure higher dust concentrations than the personal sampler. There were also serious questions about its accuracy.

Research and Development Activities

During 1998-1999, NIOSH did a number of underground studies to assess the viability of the MMRDM. Clusters of current conventional personal dust samplers were placed at locations typical of where MMRDMs might be mounted on mining equipment. Their dust concentration readings were compared with those from identical samplers worn by miners in the working face area of the mine. Results showed that there was no consistent relationship between personal sampling equipment worn by workers and area samples taken by the MMRDM on the mining machine. These data proved that the MMRDM would be inadequate for compliance sampling of operator dust exposure and gave little meaningful information about the actual dust exposure of workers.

R&D Outputs and Transfer Activities

A NIOSH report on this study was written, and the findings were first presented at MSHA headquarters. The findings were then provided to both industry and labor at a number of meetings to discuss the overall issue of improved coal dust sampling in underground coal mines. The results were also presented at national and international conferences, and published in a peer-reviewed journal.

Description of Intermediate Outcome

These findings were instrumental in getting MSHA, in the fall of 2000, to drop its 15-year long initiative to develop an MMRDM. Then, through an industry-labor-NIOSH partnership, a decision was made to turn all of the MMRDM resources toward developing a person-wearable real-time continuous dust monitor. This has resulted in the evolution of the personal dust monitor (PDM) over the past 5 years, a device that is showing great promise.

Outputs

2 Outputs

Title	Year	Output Type	Strategic Goal
Inaccuracy of Area Sampling for Measuring the Dust Exposure of Mining Machine Operators in Coal Mines Kissell-FN; Sacks-HK | Mining Engineering, 54(2), 2002 Feb; :33-39	2002	Publication	Respiratory diseases
Test Report on the Machine-Mounted Continuous Respirable Dust Monitor Kissell-FN; Thimons-ED | Proc Seventh International Mine Ventilation Congress, 2001, (Krakow, Poland); :253-260	2001	Publication	Respiratory diseases

Intermediate Outcome related to Reducing Coal Dust Exposures Through Improved Monitoring and Control

Reducing Miners' Dust Exposure Through the Use of Confining Sprays for Flooded-bed Scrubbers

Description of Problem

Side sprays positioned on each side of the frame of the continuous mining machine

Some flooded-bed scrubbers on continuous mining machines have poor inlet dust capture efficiencies. This results in higher dust levels for workers at the face of the mine. High inlet dust capture efficiency means that the scrubber captures a high proportion of the dust generated by the miner cutting the coal. Most continuous miners have a flooded-bed scrubber that pulls dust-laden air through multiple inlets located on the underside of the cutting boom. Dust is then scrubbed out of the air by passing the air through a filter that is continuously wetted by water sprays. The cleaned air is then discharged at the rear of the continuous miner. As coal is cut and loaded, a dust cloud forms beneath the cutting boom. An efficiently designed ventilation and scrubber system will result in the capture of most of the dust cloud by the scrubber inlets. If the water spray system and ventilation system are properly designed, the dust cloud will be confined near the scrubber inlets, leading to high inlet dust capture efficiency.

Unfortunately, in many continuous mining operations, forward air velocities are minimal. This allows the dust cloud to bypass the inlets and move in an outby direction toward the miner operator. The problem is exaggerated in higher-seam operations where the cutting boom confinement is less and the open area over the miner is greater.

Research and Development Activities

NIOSH research explored alternative methods to improve scrubber inlet dust capture efficiency at low face air velocities. Field studies in 1999 showed that strategically placed water sprays (confining sprays) could confine dust beneath the cutting boom, leading to improved capture of the dust cloud by the scrubber inlets. Placed near the hinge point of the cutting boom, these sprays induce additional airflow along the chassis of the continuous mining machine to limit outby movement of the dust cloud and to allow sufficient time for the dust cloud to be captured

by the scrubber inlets. NIOSH lab testing of this concept allowed for further improvements and further confirmed that a well-designed confining spray system could greatly increase dust capture by scrubber systems. The resulting benefit is lower dust exposures for miners in the face area.

R&D Outputs and Transfer Activities

NIOSH researchers distributed these findings through a number of forums. The research was published in a peer-reviewed journal and presented at several major mining conferences. The information was also presented to the United Mine Workers of America at training sessions for their mine safety representatives.

Description of Intermediate Outcome

A major continuous mining machine manufacturer, at the request of several mine operators, will now provide blocking spray systems on its continuous mining machines when requested. This technology has been accepted by the industry. Dozens of continuous miners now have such sprays as part of their standard spray system, either provided as original equipment or installed by the mine.

Outputs

1 Output

Title	Year	Output Type	Strategic Goal
Using Water Sprays to Improve Performance of a Flooded-Bed Dust Scrubber Goodman-GV | Applied Occupational and Environmental Hygiene; 15(7), 2000 Jul; 550-560	2000	Publication	Respiratory diseases

Strategic Program Outcome for Respiratory Diseases

Reducing Silica Exposures in Mining Through Improved Control Technologies

In the past 15 years, significant gains in fighting silicosis have been realized across the mining industry, as shown below:

	Percent of samples exceeding permissible exposure limit	
	1990-1994	2000-2004
Coal	27	17
Metal	26	17
Nonmetal	27	19
Stone	22	11
Sand and gravel	18	11

These gains are due in large part to the development of new dust control technology by NIOSH. Of course, new technology was not solely responsible for these improvements. Strong enforcement by the Mine Safety and Health Administration (MSHA) and changing attitudes within the mining industry were vital. Nevertheless, NIOSH made a critical contribution by providing many of the engineering control tools that made these gains possible.

Research on silica controls has involved two unique challenges that made it different from coal dust research. First, a wide variety of industries had a silica problem. This ruled out "one technology fits all" solutions. The second challenge was the low dust levels that had to be attained. It is not unusual to have a mixed dust permissible exposure limit (PEL) of 0.5 mg/m3 or less. These levels can be hard to meet, especially in underground mining.

Over the years, NIOSH has worked to stay ahead of the problem in various ways. MSHA routinely analyzes inspector samples for silica content. NIOSH periodically reviews the MSHA data to identify occupations/areas of excessive silica exposure and refocuses control research in these areas. In this way, the highest exposure occupations in mining are addressed by NIOSH research.

For example, in underground coal mining, occupations that are involved with drilling into rock surrounding the coal seam are typically at the highest silica exposure risk. For roof bolter operators, 25% of samples exceeded the PEL from 1990 to 2004. NIOSH research has shown that roof bolter operators get exposed to silica dust that is released by the roof bolting machine. However, most of their exposure comes from working downwind of the continuous mining machine. Research to provide a clean air source for bolter operators when working downwind of the continuous mining machine has led to the development of a canopy air curtain system. This air curtain is mounted to the underside of the bolter canopies and is above the bolter operator while drilling is ongoing. The air curtain filters a portion of the air entering the bolter entry and blows the cleaned air down over the breathing zone of the bolter operator. Lab testing showed that a 60% reduction in dust (silica) levels could be achieved beneath the air curtain. Results of subsequent underground testing have been promising. A major manufacturer of roof bolters has requested to work with NIOSH to further refine this system for commercialization on its machines.

Another high-risk occupation is that of highwall drill operators at surface mines. During 1990-2004, 36% of samples from these workers exceeded the PEL. To reduce dust for these workers, our research has identified deficiencies in the "Rotoclone" type of dust collector on drills, improved the efficiency and established maintenance procedures for dry collectors, and reduced dust emissions from secondary sources. Significant research has also been done over the last few years to improve the protection given by enclosed cabs on mobile mining equipment. Intervention studies have shown that appropriate filtration systems along with improving cab sealing can reduce dust levels in the cab by 90% or more. Key implementation and operating parameters were identified in this cab research and compiled into a video that shows these parameters. MSHA has placed this video on its website as a tool for mine workers. In addition, NIOSH personnel have worked with a filter manufacturer to develop a new methodology for field testing cab filtration systems for leakage. This test can be done in less than 30 minutes in the field, and a patent application has been filed. This technology will allow mine personnel and mine inspectors to quickly and accurately evaluate the dust (silica) protection provided by cabs.

In processing mills, during 1990-1994, 38% of bagging operator samples exceeded the PEL. As a result of these high exposures, NIOSH conducted research that led to the development of an improved nozzle design for loading bags, a bag and belt cleaner that removes dust from the outside of the bags, an overhead air supply island (OASIS) that provides filtered airflow for workers, and a total mill ventilation system that reduces ambient dust levels throughout a plant. These technologies have been widely accepted and implemented throughout the industry. The bag-filling nozzle has become the standard technology used by the industry, while two different manufacturers are building the bag-cleaning system. These control technologies have been summarized in a compilation of publications on minerals processing dust control that has been widely distributed. In 2002, the Occupational Safety and Health Administration placed this compilation of reports on its website for companies seeking to improve silica dust control. A major manufacturer recently requested copies of this compilation and, at its own expense, had it translated into Spanish for its operations in Mexico.

NIOSH has also developed a new method for cleaning dust from workers´ clothes. A worker´s exposure can increase by as much as 1 mg/m3 from dust liberated by soiled work clothes. For workers in silica sand plants, this means that their silica exposure, just from soiled work clothing, is 10 times over the allowable limit. Currently, MSHA requires that workers use a vacuum to remove dust from their clothing. This method is time-consuming, difficult, and inefficient. Working in partnership with a silica sand plant, NIOSH developed and tested a clothes-cleaning system that uses compressed air nozzles to blow dust from workers´ clothes in a cleaning booth. The worker is required to wear a respirator, goggles, and hearing protection during the process. Field testing at the silica plant showed that the clothes-cleaning booth was 10 times faster and 50% more efficient in removing dust from soiled clothes compared to the vacuuming method. Using compressed air for clothes cleaning is not currently accepted by MSHA. However, the silica sand producer has received a petition for modification with MSHA in order to use this method in its U.S. plants. The company is also pursuing installation of these cleaning booths in its plants abroad. Several other companies are now preparing petitions for modification to allow them to implement the system in their operations.

Intermediate Outcomes

- Compilation of Minerals Processing Publications Assists Industry with Implementing Effective Dust Control Technologies
- Engineering Control Technologies Reduce Drill Operator Dust Exposure
- Improvements in Mobile Equipment Cabs to Reduce Dust Exposure
- New Clothes-Cleaning Method Reduces Worker Silica Exposure

Intermediate Outcome related to Reducing Silica Exposures in Mining Through Improved Control Technologies

Compilation of Minerals Processing Publications Assists Industry with Implementing Effective Dust Control Technologies

Description of Problem

In mineral processing plants, workers do many different job functions and tasks that expose them to high concentrations of respirable dust. When the product being processed at these operations contains silica, the health hazard to workers can be even more serious since allowable silica exposures are 20 times lower than respirable coal dust levels. A significant problem for the industry has been the lack of a single source of information that provides practical control solutions to lower respirable dust exposures to these workers.

The OASIS system provides filtered air for plant worker

Research and Development Activities

NIOSH has developed many practical dust control technologies that have been recognized by the minerals processing industry as effective for lowering workers' respirable dust exposures. Some examples of these are the dual-bag nozzle system and the overhead air supply island system (OASIS). These were developed to lower the respirable dust exposure of workers performing bag-loading processes. A bag and belt cleaning device and automated and semiautomated palletizing systems were developed and/or tested by NIOSH to lower the respirable dust exposures of workers performing the bag-stacking process. NIOSH also designed the total mill ventilation system to lower the respirable dust exposure to all workers throughout an entire mineral processing plant.

In the past, information on dust control technology for minerals processing, most of which was developed by NIOSH or the former U.S. Bureau of Mines (USBM), was available only by reviewing a vast array of publications. These included various conference proceedings papers, journal articles, and NIOSH and USBM publications. NIOSH has since combined the various individual reports and papers written over the years into a single compilation. The dust control technology contained within this compilation has been accepted by the industry to successfully lower respirable dust exposures to workers performing various job functions. By combining this varied information on NIOSH-developed and tested control technologies into a single compilation, NIOSH provided the industry with a convenient, single source of information to lower respirable

dust exposures to its workers. While years of research effort went into developing the control technologies presented in the compilation, its actual preparation required minimal work other than organizing the information into the most user-friendly format. As new findings on practical and economically viable controls result from NIOSH research, the relevant published reports are added to the compilation. In general, the compilation of publications is updated every 2 to 3 years, depending on stakeholder need.

R&D Outputs and Transfer Activities

At least six of the control technologies described in the compilation have been developed into commercial products by manufacturers and are available to the industry. Most of the NIOSH-developed techniques listed in this compilation are being used by the industry and are considered by the industry to be practical and economically viable dust control technologies. To facilitate technology transfer, NIOSH researchers, when giving presentations at conferences, workshops, and industry meetings, make attendees aware of this compilation of reports and distribute it to interested customers. NIOSH also makes copies of the compilation available to industry associations and labor unions. A minimum of 500 copies have been distributed to industry-related individuals. No information is available on how many copies have been reproduced by individuals outside of NIOSH or how many copies have been accessed through the Web.

Description of Intermediate Outcome

Fifty to sixty copies of this compilation of publications are normally requested annually by industrial health and safety personnel. In 2002, the Occupational Safety and Health Administration (OSHA) posted it on its website (http://www.osha.gov/SLTC/silicacrystalline/dust/). Unimin Corp., the largest U.S. silica sand producer with operations throughout the world, has been distributing this compilation to its health and safety personnel throughout the corporation. In an effort to effectively distribute this information to its Spanish-speaking operations throughout the world, Unimin has recently decided to have the compilation translated into Spanish at the company's own expense.

At the 1997 National Conference to Eliminate Silicosis held in Washington DC, the plant manager from U.S. Silica's Mill Creek Facility discussed engineering controls used in his facility to reduce respirable dust exposures to workers. Of the dozen dust control techniques that he presented, eight were developed by NIOSH or the USBM and are included in the minerals processing compilation of publications. Since this conference, other dust controls have been developed and tested, and the relevant published papers describing them have been added to the compilation.

More than 100,000 individuals work in minerals processing operations throughout the United States. The control technologies presented in this compilation can reduce exposures to respirable dust and silica from 30% to 90%. Thus, the potential health impact of the information contained in the compilation is evident.

Outputs

46 Outputs

Title	Year	Output Type	Strategic Goal
Acoustical Considerations in the Design of Minerals Processing Plants Burks-JA; Rider-JP; Cecala-AB | In: Proceedings of the 1998 National Conference on Noise Control Engineering (Noise-Con 98), 1998; :443-448	1998	Publication	Hearing loss; Respiratory diseases
Adding Foam to Control Dust in Minerals Processing Volkwein-JC; Cecala-AB; Thimons-ED | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 8808	1983	Publication	Respiratory diseases
Automation to Control Silica Dust During Pallet Loading Cecala-AB; Covelli-A | Min Eng 43(12):1440-1443	1991	Publication	Respiratory diseases
Automation to Control Silica Dust During Pallet Loading Process Cecala-AB; Covelli-A | SME preprint 90-28. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :1-5	1990	Publication	Respiratory diseases
Bag and Belt Cleaner Reduces Employee Dust Exposure Cecala-AB; Timko-RJ; Prokop-AD | Rock Prod 100 (3),1997 Mar; :41-43	1997	Publication	Respiratory diseases
Closing the Door on Dust - Dust Exposure of Bag Operator and Stackers Compared for Commercial Bag Valves Cecala-AB; Muldoon-T | Pit quarry 78(11); :36-37	1986	Publication	Respiratory diseases
Dust Control in Coal Prep and Mineral Processing Plants Divers-EF; Cecala-AB | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9248	1990	Publication	Respiratory diseases
Dust control in Coal Preparation and Mineral Processing Plants Cecala-AB; Divers-EF | In: Proceedings of 1990 Joint Power Generation Conference	1990	Publication	Respiratory diseases
Dust Reduction Capabilities of Five Commercial Bag Valves Cecala-AB; Covelli-A; Thimons-ED | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines Information Circular 9068	1986	Publication	Respiratory diseases
Evaluation of a Local Exhaust Ventilation System for Controlling Refractory Ceramic Fibers During Disc Sanding Dunn-KH; Shulman-SA; Cecala-AB; Venturin-DE | J Occup Environ Hyg 2004. 2004 Oct 1(10):D107-111	2004	Publication	Mine disasters
General Ventilation Reduces Mill Dust Concentrations Cecala-AB; Mucha-R | Pit quarry 84(1):48-53	1991	Publication	Respiratory diseases
Impact of Background Sources on Dust Exposure of Bag Machine Operator Cecala-AB; Thimons-ED | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9089	1986	Publication	Respiratory diseases
Improved Dust Control for Bag Handlers Cecala-AB; Zimmer-JA; Smith-B; Viles-S | Rock Products 2000 Apr 103(4); :46-49	2000	Publication	Respiratory diseases
Industrial Hygiene from Mining Research: Three Cost-Effective Dust Control Techniques for Mineral Processing Operations Cecala-AB | Appl Ind Hyg J 3(8); :23-25	1988	Publication	Respiratory diseases
Lowering Respirable Dust Exposures at Mineral Processing Facilities Cecala-AB; Timko-RJ; Thimons-ED | In: Proceedings of the Eighth U.S. Mine Ventilation Symposium, Tien JC, ed., Rolla, MO: University of Missouri-Rolla Press,1999; :221-227	1999	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Lowering Respirable Dust Exposures at Mineral Processing Facilities Cecala-AB; Timko-RJ; Thimons-ED | In: Proceedings of 104th Annual Northwest Mining Association Conference (Spokane, WA, December 1998)	1998	Publication	Respiratory diseases
Methods to Lower Dust Exposures at Mineral Processing Operations Cecala-AB; Daniel-JH; Thimons-ED | Appl Occupational and Environmental Hygiene 11(7), 1996; :854-859	1996	Publication (guidelines)	Respiratory diseases
Methods to Lower Dust Exposures at Mineral Processing Operations Cecala-AB; Thimons-ED | In: Proceedings of National Stone Association's 1997 Environmental Safety and Health Forum, 1997; :231-249	1997	Publication (guidelines)	Respiratory diseases
Methods to Lower the Dust Exposure of Bag Machine Operators and Bag Stackers Cecala-AB; Timko-RJ; Thimons-ED | Applied Occupational Environmental Hygiene 2000 Oct; 15(10):751-765	2000	Publication	Respiratory diseases
Moisture Application for Dust Control Volkwein-JC; Cecala-AB; Thimons-ED | Appl Ind Hyg J 4(8):198-200	1989	Publication	Respiratory diseases
New Bag Nozzle System Reduces Dust From Fluidized Air Bag Machines Cecala-AB; Volkwein-JC; Thimons-ED | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 8886	1984	Publication	Respiratory diseases
New Bag Nozzle System Reduces Dust Generated During Bag Filling Cecala-AB; Muldoon-T | Rock Prod Jul; :32-33	1985	Publication	Respiratory diseases
New Dual-Bag Nozzle System Cecala-AB; Thimons-ED | Ceram Eng Sci Proc 10(1-2); :36-41	1989	Publication	Respiratory diseases
NIOSH Hazard Controls 31: Dust Protection for Bag Stackers NIOSH | Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, HC 31, DHHS (NIOSH) Publication No. 2001-142, 2001 Jul :1-4	2001	Publication	Respiratory diseases
Pallet Loading Dust Control System Cecala-AB; Covelli-A | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 9197	1988	Publication	Respiratory diseases
Reducing Bag Operator's Dust Exposure in Mineral Processing Plants Cecala-AB; Volkwein-JC; Daniel-JH | Appl Ind Hyg J 3(1); :23-27	1988	Publication	Respiratory diseases
Reducing Bag Operator's Dust Exposure in Mineral Processing Plants Cecala-AB; Volkwein-JC; Daniel-JH | In: Proceedings of the Seventh International Pneumoconioses Conference (Pittsburgh, PA, August 23-26, 1988). Part 2. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 90-108; :996-1000	1990	Publication	Respiratory diseases
Reducing Dust Exposure of Workers During Bag Stacking in Enclosed Vehicles Cecala-AB; Covelli-A; Thimons-ED | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9148	1987	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Reducing Respirable Dust Concentrations at Mineral Processing Facilities Using Total Mill Ventilation System Cecala-AB; Klinowski-GW; Thimons-ED | SME preprint 94-27. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :1-5	1994	Publication	Respiratory diseases
Reducing Respirable Dust Concentrations at Mineral Processing Facilities Using Total Mill Ventilation Systems Cecala-AB; Thimons-ED; Klinowski-GW; | Mining Engineering 47(6), 1995; :575-576	1995	Publication	All
Reducing Respirable Dust Concentrations at Mineral Processing Facilities Using Total Mill Ventilation Systems Cecala-AB; Klinowski-GW; Thimons-ED | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, RI 9469, 1993 Jan; :1-11	1993	Publication	Respiratory diseases
Reducing Respirable Dust Levels During Bag Conveying and Stacking Using Bag and Belt Cleaner Device Cecala-AB; Timko-RJ; Prokop-AE | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 9596. NTIS stock number: PB96-135470	1995	Publication	All
Reducing Silica Exposure in Aggregate Operations Cecala-AB; Organiscak-JA; Page-SJ; Thimons-ED | Aggregates Manger 2005 Jan; :24-28	2002	Publication (guidelines)	Respiratory diseases
Reducing Workers Dust Exposure During Bag Stacking in Enclosed Vehicles Cecala-AB; Covelli-A; Thimons-ED | Am Ind Hyg Assoc J 50(2); :99-104	1989	Publication	Respiratory diseases
Respirable Dust Evaluation of Two Portland Cement Operations: Part 1 of 2 Cecala-AB; Timko-RJ; Zimmer-JA; Thimons-ED | Cement Americas 2000 Jan/Feb; :20-23	2000	Publication	Respiratory diseases
Respirable Dust Evaluation of Two Portland Cement Operations: Part 2 of 2 Cecala-AB; Timko-RJ; Zimmer-JA; Thimons-ED | Cement Americas 2000 Mar/Apr; :28-30	2000	Publication	Respiratory diseases
Significant Dust Exposures from Background Sources Cecala-AB; Thimons-ED | Pit quarry 79(12); :46-51	1987	Publication	Respiratory diseases
Some Factors Impacting Bag Operator's Dust Exposures Cecala-AB; Thimons-ED | Pit quarry 85(5):38-40	1992	Publication	Respiratory diseases
Steam Reduces Dust Levels at Mineral Processing Plant Cecala-AB; Volkwein JC; Thimons-ED | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 8935, 1985	1985	Publication	Respiratory diseases
Supplementing Your Dust Control Equipment with Whole-Plant Ventilation Cecala-AB | Powder and Bulk Eng, 12(1), 1998 Jan; :19-32	1998	Publication	Respiratory diseases
Technology news 207 - New Bag Nozzle System Reduces Dust During Bagging Operations USBM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Technology News 207, 1984	1984	Publication	Respiratory diseases
Technology news 240 - Reduce Dust Exposure During Bag Filling and Stacking USBM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Technology News 240, 1986	1986	Publication	Respiratory diseases
Technology news 299 - Reduce Bagging Machine Operator's Dust Exposure by Controlling Background Dust Sources USBM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Technology News 299, 1988	1988	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Technology news 328 - New Pallet Loading System Lowers Worker's Dust Exposure and Improves Bag Stacking Process USBM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Technology News 328, 1989	1989	Publication	Respiratory diseases
Technology News 437 - Total Mill Ventilation System for Mineral Processing Facilities USBM | US Bureau of Mines, Technology News 437, 1994 May; :1-2	1994	Publication	Mine disasters
Tips for Reducing Dust from Secondary Sources During Bagging Cecala-AB; Thimons-ED | Powder and Bulk Eng 7(5):77-84	1993	Publication	Respiratory diseases

Intermediate Outcome related to Reducing Silica Exposures in Mining Through Improved Control Technologies

Engineering Control Technologies Reduce Drill Operator Dust Exposure

Description of Problem

Visible dust reduction using a wet drilling technique to drill overburden blast holes

Dust exposures at surface mines often exceed allowable levels, particularly the exposure of drill operators. During 1985-1992, 77% of drill operator silica dust samples at surface mines exceeded the permissible exposure limit. This serious overexposure to silica indicated the need for vigorous research to reduce dust at surface mine drilling operations to reduce the exposures of drill operators and helpers to acceptable levels. To make the research findings acceptable to the industry, it was necessary to develop control technologies that were economically viable for the industry to implement.

Research and Development Activities

NIOSH has conducted several projects to develop technologies to reduce dust at surface mine drill sites. These include studies to (1) measure the dust collection efficiency of the commonly used "Rotoclone" dust collector, (2) establish the optimum water flow rates for wet drilling, (3) establish the dust reductions obtained with better maintenance of dry collectors, (4) improve the dust capture efficiency of the dust collection system, (5) reduce the secondary dust emissions from the dust collection system, and (6) identify the impact of dust collection system malfunctions and to allow mine operators to evaluate the performance of drill dust collection systems. To the greatest extent possible, all of this research was carried out in partnership with equipment manufacturers and mining companies to facilitate the eventual transfer of the developed technologies to the industry.

R&D Outputs and Transfer Activities

Research results were transferred through peer-reviewed publications, trade journals, Technology News flyers, and conference presentations. NIOSH produced an educational pamphlet entitled "Silica...It's Not Just Dust." This pamphlet won the U.S. Public Health Service Engineering Literary Award in 1998 and helped to educate drillers about the hazards of silica dust. NIOSH is requested annually by the United Mine Workers of America to present surface mine research results to mine personnel at the Mine Safety and Health Academy near Beckley, WV. In addition, NIOSH personnel are routinely requested to give presentations to surface mine personnel in MSHA regions, particularly where silica exposures are highest.

Description of Intermediate Outcome

Dust samples exceeding the exposure limit dropped from 77% during 1985-1992 to 31% during 1996-2000. NIOSH research was an important contributor to this reduction. For example, NIOSH showed that Rotoclone dust collectors, a commonly used device, were not satisfactorily controlling operator exposure and that simple improvements could be made to reduce dust levels around the drill rigs. These results were cited by Marvin Nichols, then the Administrator for Coal Mine Safety and Health in MSHA, in an agency memorandum regarding procedures for assessing compliance with 30 CFR 72.620. MSHA now prohibits Rotoclone collectors at surface coal mines. MSHA also used NIOSH research results in a 1998 court case for civil penalty proceedings against a mining company (MSHA v. Hobet Mining, docket Nos. WEVA 96-170, 185, 178; 97-33. August 31, 1998).

Outputs

24 Outputs

Title	Year	Output Type	Strategic Goal
Assessment of Airborne Dust Generated From Small Truck-Mounted Rock Drills Organiscak-JA; Page-SJ | USBM, RI 9616. NTIS stock number: PB96-155098, 1995 :1-11	1995	Publication	Respiratory diseases
Characteristics of Fugitive Dust Generated from Unpaved Mine Haulage Roads Organiscak-JA; Reed-WR | Int J Surface Min Reclam Environ 18(4)2004; :236-252	2004	Publication	Respiratory diseases
Current NIOSH Dust Control Research for Noncoal Surface Mines Cecala-AB; Organiscak-JA; Page-SJ; Heitbrink-WA; Thimons-ED | Proc National Stone, Sand & Gravel Association Environment, Safety & Health Forum 2001 Sept Arlington, VA: National Stone, Sand & Gravel Association, 2001; :87-100	2001	Publication	Respiratory diseases
Development of a Dust Collector Inlet Hood for Enhanced Surface Mine Drill Dust Capture Organiscak-JA; Page-SJ | Int J Surface Min Reclam Environ 19(1):12-28	2005	Publication	Respiratory diseases
Dust Underfoot: Enclosed Cab Floor Heaters Can Significantly Increase Operator's Respirable Dust Exposure Cecala-AB; Organiscak-JA; Heitbrink-WA | Rock Products 2001 Apr; 104(4):39-44	2001	Publication	Respiratory diseases
Evaluation of Dust Exposure to Truck Drivers Following the Lead Haul Truck Reed-WR; Organiscak-JA | SME preprint 05-10. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2005; :1-9	2005	Publication	Respiratory diseases
Field Assessment of Control Techniques and Long-Term Dust Variability for Surface Coal Mine Rock Drills and Bulldozers Organiscak-JA; Page-SJ | International Journal of Surface Min Reclam Environ, 13 1999; :165-172	1999	Publication	Respiratory diseases
Handbook for Dust Control in Mining NIOSH | NIOSH Pub No. 2003-147, IC 9465, 2003 Jun; :1-131	2003	Publication	Respiratory diseases
New Approach Controls Dust at the Collector Dump Point: NIOSH Finds a Simple, Cost-Effective Solution for Reducing Dust for Blasthole Drills Reed-WR; Organiscak-JA; Page-SJ | Eng Min J 204(7), 2004; :29-31	2004	Publication	Respiratory diseases
New Approach Controls Dust at the Collector Dump Point: NIOSH Finds a Simple, Cost-Effective Solution for Reducing Dust for Blasthole Drills Reed-WR; Organiscak-JA; Page-SJ | Coal Age 2004 109(6), 2004 Jun; :20-22	2004	Publication	Respiratory diseases
NIOSH Hazard Controls 27 - New Shroud Design Controls Silica Dust from Surface Mine and Construction Blast Hole Drills Page-SJ; Organiscak-JA; Flesch-JP; Hagedorn-RT | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98-150, 1998 Nov; : 1-4	1998	Publication	Respiratory diseases
NIOSH/Industry Collaborative Efforts Show Improved Mining Equipment Cab Dust Protection Organiscak-JA; Cecala-AB; Thimons-ED; Heitbrink-WA; Schmitz-M; Ahrenholtz-E | In: Yernberg WR, ed. Transactions of Society for Mining, Metallurgy, and Explorations, Inc., Vol. 314. Littleton, CO: Society for Mining, Metallurgy, and Explorations, Inc., 2003; :145-152	2003	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Reducing Enclosed Cab Drill Operator's Respirable Dust Exposure at a Surface Coal Operation Using a Retrofitted Filtration and Pressurization System Cecala-AB; Organiscak-JA; Heitbrink-WA; Zimmer-JA; Fisher-T; Gresh-RE, et al. | In: Yernberg WR, ed. Transactions of Society for Mining, Metallurgy, and Explorations, Inc. Vol. 314. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :31-36	2003	Publication	Respiratory diseases
Reducing Silica Exposure in Aggregate Operations Cecala-AB; Organiscak-JA; Page-SJ; Thimons-ED | Aggregates Manger 2005 Jan; :24-28	2002	Publication (guidelines)	Respiratory diseases
Retrofit Options for Better Dust Control Chekan-GJ; Colinet-JF | Aggregates Manag 8(9); :9-12	2003	Publication (guidelines)	Respiratory diseases
Semiempirical Model for Predicting Surface Coal Mine Drill Respirable Dust Emissions Page-SJ; Organiscak-JA | Int J Surface Min Reclam Environ 18(1), 2004; :42-59	2004	Publication	Respiratory diseases
Silica...It's Not Just Dust MSHA, OSHA, NIOSH | Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, HC27, DHHS (NIOSH) Publication No. 97-118	1997	Publication	Respiratory diseases
Static Pressure Requirements for Ventilated Enclosures Heitbrink-WA; Thimons-ED; Organiscak-JA;, Cecala-AR; Schmitz-M; Ahrenholtz-E | In: Progress in Modern Ventilation. Vol 2. Proceedings of the Ventilation 2000 - 6th International Symposium on Ventilation for Contaminant Control [Helsinki, Finland, June 4-7, 2000). Helsinki, Finland: Finnish Institute of Occupational Health; :97-99	2000	Publication	Respiratory diseases
Taming the Dust Devil: an Evaluation of Improved Dust Controls for Surface Coal Mine Drills Using Rotoclone Collectors Page-SJ; Organiscak-JA | Eng Min J 196(11); :30-31	1995	Publication	Respiratory diseases
Technology News 447 - Dust Collector Discharge Shroud Reduces Dust Exposure to Drill Operators at Surface Coal Mines USBM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Technology News 447, 1995	1995	Publication	Respiratory diseases
Technology News 485 - Improved Cab Air Inlet Location Reduces Dust Levels and Air Filter Loading Rates NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 485, 2001 Feb :1-2	2001	Publication	Respiratory diseases
Technology News 487 - Sweeping Compound Application Reduces Dust From Soiled Floors Within Enclosed Operator Cabs NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 487, 2001 Mar :1-2	2001	Publication	Respiratory diseases
The Effects of Low Quartz Mass Loading and Spatial Variability on the Quartz Analysis of Surface Coal Mine Dust Samples Page-S; Organiscak-J; Mal-T | Appl Occup Environ Hyg 16(9), 2001 Sept; :910-923	2001	Publication	Respiratory diseases
Validation of a Dust Dispersion Model for Haul Trucks Reed-WR | Trans Soc Min Metal Explor. Vol. 316. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :163-170	2004	Publication	Respiratory diseases

Intermediate Outcome related to Reducing Silica Exposures in Mining Through Improved Control Technologies

Improvements in Mobile Equipment Cabs to Reduce Dust Exposure

Description of Problem

Cabs on mobile equipment at surface mines, particularly older equipment, provide little, if any, dust protection. Many cabs are not properly designed for dust control in the first place. As the cabs age, the seals around the doors and at locations where controls enter the body of the cab degrade. This allows dusty air to enter the cab. In addition, for a cab to provide meaningful dust protection, positive air pressurization within the cab is needed. Few older cabs, and many new cabs, cannot maintain this positive air pressurization. Mobile equipment (such as drills, graders, loaders, dozers, and trucks) operate at surface mines and construction sites throughout the United States. Workers in the cabs are often overexposed to respirable dust and silica. For example, data from the Mine Safety and Health Administration (MSHA) have shown a 9% silicosis rate in central Pennsylvania surface coal miners. Many of these miners work in cabs.

Cab filtration and pressurization systems prevent dust from penetrating cabs reducing respirable dust exposure

Research and Development Activities

NIOSH began collaborating with MSHA, mine operators, and equipment manufacturers to find the most cost-effective ways to improve dust protection in cabs. While most of this work was done at actual field sites, some of it included lab studies at the Pittsburgh Research Laboratory and at cooperator facilities. In nine NIOSH field demos, economical and viable ways to improve dust protection for workers in enclosed cabs have been shown. NIOSH researchers, in partnership with mining companies and equipment suppliers of filtration systems and assisted by MSHA, showed that cabs providing almost no dust protection could show major improvements when simple changes were made to the cab. The two most important factors needed to achieve low dust levels were an efficient air filtration system (high-efficiency intake and recirculation filters) and an effectively sealed (tight) cab for positive inside cab pressurization. In most cases, the overall cost of the improvements was less than $5,000. In addition, the introduction of efficient filtration systems on the cabs was usually accompanied by putting good air conditioning and heating systems on at the same time. Miners are thus more comfortable in their cabs and are more apt to keep the cab doors closed. This further protects them from outside dust. Results of the field demos showed that a 90% reduction in respirable dust could

be achieved if proper cab filtration was applied and air leaks in the cab were reasonably sealed by replacing door seals and patching up holes in the body of the cab. In most cases, the improvements yielded a cab average silica dust level below 100 µg/m^3 (the silica or quartz permissible exposure limit) at moderate to high outside dust levels.

R&D Outputs and Transfer Activities

NIOSH published these findings in peer-reviewed journals, trade journals, and conference proceedings. Trade journals and conferences were selected to reach the appropriate target audience. Technical presentations were made at conferences and at mine corporate safety and health meetings A video that gives guidelines for effectively protecting cabs was also produced. The video is now available from the MSHA Catalog of Training Products for the Mining Industry (http://www.msha.gov/TRAINING/prodintr.htm). Hundreds of copies of the video have been distributed to mining companies around the world. Major unions, such as the United Steelworkers of America and the International Union of Operating Engineers, have requested copies of the video. Trade organizations such as the Industrial Minerals Association-North America and the National Stone, Sand & Gravel Association, have also asked for the video.

Description of Intermediate Outcome

One project collaborator, a filter supplier, saw an aftermarket develop for the use of its retrofit intake filtration pressurization systems for mining and related (construction) equipment cabs. While NIOSH has not been able to get any sales numbers, the supplier continues to offer the systems after several years and continues to work with NIOSH in further improving cab dust control.

MSHA dust sampling data from surface mines now show a meaningful reduction in the fraction of workers overexposed to silica. From 1991 to 2004, drill operator exposures fell by 30%, bulldozer operators by 46%, scraper operators by 75%, refuse truck drivers by 75%, and front-end loader operators by 33%. The overall reduction was 40%. While we do not have a good feel for how many cabs have been changed because of this research, we believe, based on industry and labor interest in the findings, that improved cabs account for some of the improvement. Although engineering controls developed through NIOSH research have clearly played a role in this reduction, the education of workers and the enforcement of dust standards have also been essential. This cab research, along with other NIOSH research on surface mine dust control, have provided industry, labor, and MSHA with control technologies that have contributed to this reduction. Surface coal miners and heavy construction workers can all benefit from this NIOSH-developed cab technology.

Outputs

11 Outputs

Title	Year	Output Type	Strategic Goal
An Evaluation of Cab Filtration and Pressurization Systems: Two Case Studies Chekan-GJ; Cecala-AB; Colinet-JF | In: Proceedings of the Environment, Safety & Health Forum and Expo (Phoenix, AZ, Sept. 22-24, 2003). Alexandria, VA: National Stone, Sand & Gravel Association, 2003; :114-129	2003	Publication	Respiratory diseases
Current NIOSH Dust Control Research for Noncoal Surface Mines Cecala-AB; Organiscak-JA; Page-SJ; Heitbrink-WA; Thimons-ED | Proc National Stone, Sand & Gravel Association Environment, Safety & Health Forum 2001 Sept Arlington, VA: National Stone, Sand & Gravel Association, 2001; :87-100	2001	Publication	Respiratory diseases
Dust Underfoot: Enclosed Cab Floor Heaters Can Significantly Increase Operator's Respirable Dust Exposure Cecala-AB; Organiscak-JA; Heitbrink-WA | Rock Products 2001 Apr; 104(4):39-44	2001	Publication	Respiratory diseases
Filtered Recirculation: A Critical Component to Maintaining Acceptable Air Quality in Enclosed Cabs for Surface Mining Equipment Cecala-AB; Zimmer-JA | In: Ganguli R, Bandopadhyay S, eds. Mine ventilation: Proceedings of the 10th U.S./North American Mine Ventilation Symposium (Anchorage, AK, May 16-19, 2004). Leiden, Netherlands: Balkema, 2004 May; :377-387	2004	Publication	Respiratory diseases
NIOSH/Industry Collaborative Efforts Show Improved Mining Equipment Cab Dust Protection Organiscak-JA; Cecala-AB; Thimons-ED; Heitbrink-WA; Schmitz-M; Ahrenholtz-E | In: Yernberg WR, ed. Transactions of Society for Mining, Metallurgy, and Explorations, Inc., Vol. 314. Littleton, CO: Society for Mining, Metallurgy, and Explorations, Inc., 2003; :145-152	2003	Publication	Respiratory diseases
Reducing Enclosed Cab Drill Operator's Respirable Dust Exposure at a Surface Coal Operation Using a Retrofitted Filtration and Pressurization System Cecala-AB; Organiscak-JA; Heitbrink-WA; Zimmer-JA; Fisher-T; Gresh-RE, et al. | In: Yernberg WR, ed. Transactions of Society for Mining, Metallurgy, and Explorations, Inc. Vol. 314. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :31-36	2003	Publication	Respiratory diseases
Reducing Enclosed Cab Drill Operator's Respirable Dust Exposure with Effective Filtration and Pressurization Techniques Cecala-AB; Organiscak-JA; Zimmer-JA; Heitbrink-WA; Moyer-ES; Schmitz-M; Ahrenholtz-E; Coppock-CC; Andrews-EH | Journal of Occupational Environmental Hygiene 2(1)2005; :54-63	2005	Publication	Respiratory diseases
Reducing Silica Exposure in Aggregate Operations Cecala-AB; Organiscak-JA; Page-SJ; Thimons-ED | Aggregates Manger 2005 Jan; :24-28	2002	Publication (guidelines)	Respiratory diseases
Retrofit Options for Better Dust Control Chekan-GJ; Colinet-JF | Aggregates Manag 8(9); :9-12	2003	Publication (guidelines)	Respiratory diseases
Technology News 487 - Sweeping Compound Application Reduces Dust From Soiled Floors Within Enclosed Operator Cabs NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 487, 2001 Mar :1-2	2001	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Reducing Dust Inside Enclosed Cabs NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Videocassette	2002	Video	Respiratory diseases

Intermediate Outcome related to Reducing Silica Exposures in Mining Through Improved Control Technologies

New Clothes-Cleaning Method Reduces Worker Silica Exposure

Description of Problem

NIOSH researcher demonstrates the efficiency of the clothes cleaning process

Soiled work clothing can be a significant source of dust exposure for workers in many industries. For example, at one silica sand plant, a U.S. Bureau of Mines study documented a tenfold increase in worker respirable dust exposure from soiled clothing while workers did their normal duties. Respirable dust levels measured in this study were so high that workers would be overexposed to the 8-hour federal silica standard in less than 2 hours. The most effective way to eliminate this dust source is to have workers clean or change their work clothing. Changing work clothing during a shift is generally not practical. Cleaning of work clothing can be difficult, and, if not done properly, can actually increase dust exposures. Currently, the Mine Safety and Health Administration (MSHA) requires that worker clothing be cleaned by using a vacuuming method. This method is cumbersome and not very efficient.

Research and Development Activities

A cooperative research effort was established between Unimin Corp. and NIOSH to develop a better method to clean dust-soiled work clothing while it is still being worn. The result was a new clothes-cleaning process. To perform this new cleaning method, a worker enters a booth wearing a respirator, goggles, and hearing protection and activates an air spray manifold containing 26 vertically spaced air nozzles. As the individual rotates one or two times in front of the air spray manifold, compressed air from the nozzles blows the dust from the worker's clothing. Since the booth is under negative pressure, the dust removed from the worker's clothing is ducted away to a baghouse dust collector, discharged into the atmosphere outside the plant, or passed through a HEPA filter located on the booth and then discharged back into the plant.

Results have shown that this clothes-cleaning process is 20 times faster and removes about 40% more dust than the currently approved MSHA vacuuming method. The average cleaning time with this new process is normally less than 20 seconds. Workers found the method easy to use and very efficient.

R&D Outputs and Transfer Activities

NIOSH has transferred this information through peer-reviewed and trade journal articles. Presentations have been made at numerous conferences. In addition, NIOSH researchers have made presentations at safety and health meetings of individual companies and at industry organization meetings such as the Industrial Minerals Association-North America. NIOSH has also produced a video and instructional manual that describes the clothes-cleaning process. This video has been widely distributed throughout the U.S. minerals processing industry and is available for viewing on the NIOSH Mining Website.

Description of Intermediate Outcome

When initially developed, the new clothes-cleaning process was not approved by MSHA for use in U.S. operations. A petition for modification to allow the use of this cleaning process was submitted by Unimin Corp. and approved in June 2005. Other companies wishing to use this method need only file a similar petition to get approval. At this time, several other companies are preparing petitions for modification. The next time MSHA changes the federal regulations, it is expected that it will modify the standard to allow the use of this improved clothes-cleaning method.

Two private companies have started manufacturing the clothes-cleaning system: S. K. Bowling Co. and Superior Construction and Repair Co. In addition, there has been interest in this clothes-cleaning method in many different industries outside of mining and in many different countries, including Canada, Mexico, Australia, and Belgium. Unimin is currently making plans to incorporate it into several of its Canadian operations.

Outputs

3 Outputs

Title	Year	Output Type	Strategic Goal
Dusting Off: NIOSH Develops a New Method to Clean Dust-Soiled Work Clothes Pollock DE, Cecala AB, O'Brien AD, Zimmer JA, Howell JL | Rock Prod 108(3), 2005; :30-34	2005	Publication	Respiratory diseases
Technology News 509 - A New Method to Clean Dust From Soiled Work Clothes Cecala-AB; Pollock-DE | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH Publication No. 2005-136, Technology News 509, 2005 May; :1-2	2005	Publication	Respiratory diseases
Clothes Cleaning Process NIOSH | NIOSH 2004 Jan; :Video (VHS format)	2005	Video	Respiratory diseases

Strategic Program Outcome for Respiratory Diseases

Reducing Exposures to Diesel Emissions Through Improved Monitoring and Control

Substantial evidence has shown that underground miners are routinely exposed to very high concentrations of diesel particulate matter (DPM), much higher than for any other occupation. In 1998, the Mine Safety and Health Administration (MSHA) proposed two diesel rules - one for coal mining, the other for metal/nonmetal mining. The coal rule set a staged implementation limit on DPM emission ending at 2.5 g/hr for heavy-duty equipment and can be met by the use of MSHA-approved filters based on the diesel emission characteristics of the engines involved. The metal rule set an interim concentration limit of 400 $\mu g/m^3$ of total carbon and a final concentration limit of 160 $\mu g/m^3$ of total carbon scheduled to go into effect in January 2006.

In early 1999, with both MSHA and the American Conference of Governmental Industrial Hygienists setting limits on DPM, NIOSH convened a committee with the intent of determining a realistic exposure limit for DPM in mining. Although it was decided that an exposure limit for DPM was premature, NIOSH was, however, able to estimate a minimum DPM level achievable by using clean engines and ceramic filter technologies. This analysis was placed into the MSHA rule hearing record and published in *Mining Engineering* magazine in 2001.

Later in 1999, a coal diesel partnership was formally established among union, industry, and NIOSH. Its goal is to work together to address technology to control diesel emissions in coal mines. The partners requested that NIOSH provide a review of available technology. This was presented to the partnership in 2000 and published as NIOSH Information Circular 9462 in 2002. That same year, the metal/nonmetal industry, observing the coal partnership successes, requested that NIOSH establish a similar metal/nonmetal partnership to address diesel issues of concern in its own industry.

NIOSH researchers have greatly facilitated the implementation of diesel control technologies into both coal and metal/nonmetal mines:

- NIOSH researchers worked in conjunction with the Canadian Diesel Emissions Evaluation Program (DEEP), a consortium of Canadian industry, academics, government, and labor. NIOSH participated in an isolated zone study to determine exhaust particulate filter performance and took the initiative to conduct the world's first examination of the size distribution of diesel exhaust particles downwind of an operating vehicle. NIOSH found that the nanoparticle concentration actually increased with the use of filters, many of which were 98% efficient in removing larger particles. Based on this experience, NIOSH was able to suggest and conduct isolated zone experiments in coal and metal mines that obtained definitive assessments of the effects of engine tuning for altitude, pleated-element filters, ceramic filters, and fuels. Findings from these efforts were transferred to the U.S. mining industry through reports, conference presentations, and workshops.
- The metal/nonmetal industry contested the metal rule. In an agreement with MSHA, it demanded that NIOSH be involved in determining the proper compliance surrogate for DPM exposures in metal mines. The contested rule had incorporated the commercial version of the U.S. Bureau of Mines (USBM) diesel sampler to separate out

carbon-bearing dusts from diesel soot and used total carbon (TC) as the DPM surrogate. NIOSH worked with MSHA and the manufacturer to improve the reliability and accuracy of the commercialized version of the USBM diesel sampler. It is now the MSHA-required sampler for sampling DPM in metal/nonmetal mines. NIOSH research was instrumental in changing the surrogate from TC to elemental carbon (EC). Using EC overcame the problem of sampling interference from oil mist, carbonaceous ores, or tobacco smoke, all of which can be present in metal/nonmetal mines. NIOSH was tasked with reviewing the results of a study at 31 mines, which was agreed to under a litigation agreement between MSHA, industry, and labor. NIOSH analyzed all samples from the study, and reviewed and commented on the study results.

- Uncertainty from the metal/nonmetal industry over the real-world performance of diesel control technology resulted in two NIOSH studies in a western metal mine in 2003 and 2004. The studies verified that ceramic filters could reduce EC by 98% under actual production scenarios, biodiesel blends could reduce EC by over 40%, water fuel emulsions reduced EC by more than 80%, and differences among No. 1, No. 2, and ultralow sulfur fuels were negligible. Also, excess NO_2 was observed when platinum-catalyzed systems were used.
- In late 2002, MSHA requested NIOSH assistance in producing an industry guideline for the selection of diesel filters. NIOSH took the lead and produced a highly acclaimed Diesel Particulate Filter Selection Guide in early 2003. The guide is Web-based and leads a novice through the process of selecting the proper system for equipment requiring filters. It starts with organizational and engine maintenance/condition prerequisites and continues all the way through filter selection criteria and operational limitations. It is posted on both the MSHA and NIOSH websites.
- In 2003, NIOSH, working through the abovementioned partnerships, hosted workshops for control of diesel emissions at coal and metal/nonmetal mines. The workshops were held at several locations and transferred the latest diesel emission control technologies, Canadian experiences, and engine maintenance practices to the U.S. mining industry.
- NIOSH, working together with a private company, has developed an exhaust cooling system that reduces the diesel exhaust temperature entering high-temperature pleated-element filters, which are widely used in the coal mining industry. The cooler exhaust from this device prevents unintended ignition of the diesel soot accumulations in the filter (filter fires) that can result from uncooled exhaust.
- NIOSH is working with a diesel ceramic filter manufacturer to develop a passive (self-regenerating) filter that will regenerate at lower-duty cycle temperatures without creating an increase in tailpipe emissions and workplace concentrations of NO_2 in the mines. Successful curtailment of excessive NO_2 of this system would allow the application of passive filter technology on a wider range of underground equipment in underground mines.

As a result of NIOSH efforts, the coal and metal/nonmetal industries, labor, and MSHA have pertinent and useful results based on solid research and have a continuing resource for unbiased and factual information about technology to control diesel emissions. Better and more technology is now being implemented that will reduce miners´ exposures to diesel exhaust contaminants.

Intermediate Outcomes

- New Size-Selective Sampler for Diesel Compliance Measurements
- NIOSH Research Results in a Revised Final Rule on the Interim DPM Standard for Underground Metal/Nonmetal Mines
- NIOSH Research Supports Diesel Rule Implementation

Intermediate Outcome related to Reducing Exposures to Diesel Emissions Through Improved Monitoring and Control

New Size-Selective Sampler for Diesel Compliance Measurements

Description of Problem

More than 30,000 underground mine workers are exposed to excessively high levels of diesel particulate matter (DPM). DPM has been declared as a possible cancer-causing agent by NIOSH and others. In 1998, the Mine Safety and Health Administration (MSHA) proposed a new rule to regulate the exposure of underground metal/nonmetal miners to DPM. The agency planned to use measurements of total carbon (TC) as a surrogate for DPM. However, before the rule could be finalized, MSHA needed to solve the problem of TC interference from carbon-containing ore dust.

SKC size selective sampler

Years earlier, the U.S. Bureau of Mines (USBM) had developed a size-selective sampler that had potential to solve this TC interference problem. The sampler, developed to separate coal mine dust from DPM, prevented 90% of coal dust from being collected on the sampling media. MSHA asked NIOSH to verify that the sampler would also work for metal/nonmetal mine dusts and then develop a commercial version.

Research and Development Activities

NIOSH contracted with SKC Corp. to develop a commercial version of the USBM sampler and with the University of Minnesota to test it. In-mine and lab testing of the USBM sampler verified that the sampler would, in fact, eliminate metal/nonmetal mine dusts as desired. Subsequent NIOSH lab and field experience with the commercial version, developed in consort with MSHA, revealed that the samplers produced irregularly shaped deposit areas on the filters. NIOSH conducted research and found an innovative solution to the problem. Upon recommendations from NIOSH and MSHA, SKC replaced the crimped aluminum shield holding the filter media with a flat gasket. This resulted in precise circular deposit areas. SKC also incorporated a NIOSH recommendation to increase the filter diameter for a better fit and to include a second filter to serve as a field blank. NIOSH did extensive testing of the new commercial version to ensure its reliability and repeatability.

R&D Outputs and Transfer Activities

NIOSH, MSHA, and SKC worked as a team on this research. This joint effort greatly facilitated the transfer of the technology. Industry and labor were kept informed of progress throughout this effort. All of this stakeholder interaction made acceptance of this technology for measuring DPM in underground metal/nonmetal mines easy to achieve. The results of this research were also published in a peer-reviewed journal and have been presented at a number of technical conferences.

Description of Intermediate Outcome

The modified sampler is now a commercial product from SKC, Inc. It has become the MSHA-required sampler for measuring diesel particulate in metal/nonmetal mines (Federal Register, Vol. 67, No. 39, February 27, 2002, Rules and Regulations, p. 9180). It now represents the state of the art in measuring DPM in underground metal/nonmetal mines.

Outputs

6 Outputs

Title	Year	Output Type	Strategic Goal
A Cost-Effective Personal Diesel Exhaust Aerosol Sampler McCartney-TC; Cantrell-BK | In: Diesels in underground mines - measurement and control of particulate emissions. Proceedings of the Bureau of Mines Information and Technology Transfer Seminar, Minneapolis, MN, September 29-30, 1992. Minneapolis, MN: U.S. Department of the Interior, Bureau of Mines, Information Circular 9324; :24-30	1992	Publication	Respiratory diseases
Development of Personal Diesel Aerosol Sampler Design and Performance Criteria Cantrell-BK; Rubow-KL | Min Eng 43(2); :231-236	1991	Publication	Respiratory diseases
Evaluation of the SKC® DPM Cassette for Monitoring Diesel Particulate Matter in Coal Mines Noll-JD; Birch-E | J Environ Monit 2004 Dec; 6(12):973-978	2004	Publication	Respiratory diseases
Measurement of Coal Dust and Diesel Exhaust Aerosols in Underground Mines Rubow-KL; Cantrell-BK; Marple-VA | In: Proceedings of the Seventh International Pneumoconioses Conference (Pittsburgh, PA, August 23-26, 1988). Part 1. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 90-108; :645-65	1990	Publication	Respiratory diseases
Sampling Results of the Improved SKC® Diesel Particulate Matter Cassette Noll-JD; Timko-RJ; McWilliams-LJ; Hall-P; Haney-R | Journal of Occupational and Environmental Hygiene, 2(1), 2005 Jan; :29-37	2005	Publication	Respiratory diseases
Submicrometer Elemental Carbon as a Selective Measure of Diesel Particulate Matter in Coal Mines Birch-ME; Noll-JD | J Environ Monit 2004 Oct; 6(10), 2004 Oct; :799-806	2004	Publication	Respiratory diseases

Intermediate Outcome related to Reducing Exposures to Diesel Emissions Through Improved Monitoring and Control

NIOSH Research Results in a Revised Final Rule on the Interim DPM Standard for Underground Metal/Nonmetal Mines

Description of Problem

In January 2001, the Mine Safety and Health Administration (MSHA) promulgated a rule regulating underground metal and nonmetal miners' exposure to diesel particulate matter (DPM). The rule specified that compliance would be determined by sampling a surrogate for DPM. The surrogate was to be the concentration of total carbon (TC) measured by using a size-selective impactor sampler. Total carbon is the sum of organic carbon (OC) and elemental carbon (EC). Mining industry officials claimed that sources of OC in the mine other than DPM, such as carbonaceous ore dust, tobacco smoke, and oil mist from drills, would falsely elevate TC above that attributable to DPM. They therefore challenged the rule. The resulting settlement agreement among industry, labor, and MSHA specified that a metal/nonmetal mine study would be conducted in a variety of mines around the country. NIOSH was to be involved in the study, evaluate the data, and review and comment on the final report of the study.

Research and Development Activities

Working together, NIOSH, MSHA, and industry developed a protocol to investigate possible non-DPM sources of OC in underground metal/nonmetal mines and to evaluate the impact of those interferences on TC measurement. The mine study verified that drill oil mist and cigarette smoke could be significant sources of OC. Some sources of OC could be eliminated or corrected out. The impactor sampler eliminated mineral dust from the filter sample, and vapor-phase OC could be corrected for by applying a second filter. However, the study also concluded that the non-DPM contributions to OC from oil mist and cigarette smoke could not be avoided, nor could an appropriate correction factor be applied to account for these OC sources. Based on the research findings, the earlier (1997) position of NIOSH was verified - EC was a better surrogate for DPM than TC since the only source of EC was DPM.

R&D Outputs and Transfer Activities

Since this research effort was conducted closely with industry, labor, and MSHA, the transfer of findings was easy to achieve. Findings have been presented at workshops and partnership meetings attended by personnel from MSHA, industry, and labor. They have also been published in a peer-reviewed journal.

Description of Intermediate Outcome

As a result of this NIOSH research, MSHA, industry, and labor agreed to change the compliance surrogate for the DPM interim standard to EC, with EC being 77% of TC (Federal Register, Vol. 68, No. 157, August 14, 2003, Proposed Rules, page 48668). In addition, as the January 2006 final rule approaches, the findings of this research are being examined inasmuch as the final rule was originally written in terms of TC, not EC, as the surrogate for DPM. MSHA has already approached NIOSH for help in dealing with this issue.

Outputs

2 Outputs

Title	Year	Output Type	Strategic Goal
Diesel Exhaust Aerosol: Review of Occupational Exposure Cantrell-BK; Watts-WF Jr | Appl Occup Env Hyg 12(12), 1997; :1019-1027	1997	Publication	Respiratory diseases
Sampling Results of the Improved SKC® Diesel Particulate Matter Cassette Noll-JD; Timko-RJ; McWilliams-LJ; Hall-P; Haney-R | Journal of Occupational and Environmental Hygiene, 2(1), 2005 Jan; :29-37	2005	Publication	Respiratory diseases

Intermediate Outcome related to Reducing Exposures to Diesel Emissions Through Improved Monitoring and Control

NIOSH Research Supports Diesel Rule Implementation

Description of Problem

A diesel powered load haul dump vehicle in isolated zone study

In January 2001, the Mine Safety and Health Administration (MSHA) promulgated a new rule that regulates the exposure of metal/nonmetal miners to diesel particulate matter (DPM). However, the mining industry doubted whether the diesel emission control technology existed to meet the new rule. Many of the proposed controls had only been tested in labs. The industry asked NIOSH to conduct underground studies to determine the effectiveness of diesel emissions controls under more realistic conditions and to determine if any other adverse health or safety impacts could result from their application. NIOSH agreed to perform in situ testing only if the control technology could be tested in isolation.

Research and Development Activities

Stillwater Mining Co.'s Nye Mine in Montana offered the use of a long drift ventilated by fresh air to conduct the studies. A single vehicle ran a representative and repeatable duty cycle within this isolated drift as air contaminant measurements were obtained. Comparisons were made between air contaminant concentrations when the vehicle was operated with no control technology versus when the control technology was used. The effects of the following technologies were measured:

1. two blends of yellow grease biodiesel fuel,
2. two blends of soy-based biodiesel fuel,
3. cold and warm weather formulations of a water-fuel emulsion,
4. No. 1 versus No. 2 diesel fuel,
5. an ultralow sulfur No. 2 fuel,
6. a diesel oxidation catalyst,
7. platinum-catalyzed particulate filters,
8. a fuel-borne catalyzed particulate filter, and
9. high-temperature disposable pleated-element filters from two manufacturers.

These studies were done in two individual sets of tests during 2003-2004. Contaminants measured were CO_2, CO, NO, NO_2, and particulate matter (including total particle mass, elemental carbon, total carbon, and size distribution and number).

The findings confirmed that reductions in contaminant concentrations reported in lab studies were achievable when applied to real equipment operated under simulated production cycles. The study also confirmed an increase in NO_2 caused by platinum-catalyzed ceramic filters designed to facilitate the passive regeneration at lower-duty cycle temperatures. The elevated NO_2 emissions indicated a possible health hazard associated with the use of these filters in underground mines.

R&D Outputs and Transfer Activities

The research was done under a Metal/Nonmetal Diesel Partnership consisting of NIOSH, MSHA, industry, and labor. Working with the partnership greatly facilitated the transfer of the technology to NIOSH customers. Stakeholders participated in the mine site testing. NIOSH issued reports to the partnership detailing the research findings. Information from the studies is being published in several journals and presented at several conferences. The research results were also presented at numerous workshops and partnership meetings attended by representatives of industry, labor, and government.

Description of Intermediate Outcome

Prior to these studies, enforcement, labor, and mine operators were certain of the effectiveness of various control options in the real world. Mines were reluctant to commit to using controls with unproven effectiveness. Such concerns are no longer an issue. In the recasting of the interim diesel rule for metal/nonmetal mines, MSHA referenced the 2003 NIOSH/Stillwater study report as part of the evidence that available technologies are capable of reducing DPM. The report, entitled "The Effectiveness of Selected Technologies in Controlling Diesel Emissions in an Underground Mine: Isolated Zone Study at Stillwater Mining Company's Nye Mine," is on MSHA's website at http://www.msha.gov/01-995/dpmdocs/stillwater.pdf. The information obtained from this research has given industry an increased level of confidence that the technology to reduce worker exposure to DPM is available and works. This research did not address long-term implementation issues associated with using these technologies. Research to address long-term issues is currently being planned by NIOSH and is expected to begin in late 2005.

Outputs

15 Outputs

Title	Year	Output Type	Strategic Goal
Characterization of Diesel Aerosols in an Underground Metal Mine Bugarski-AD | In: Mayer A, ed. Proceedings of the Eighth International ETH-Conference on Nanoparticle Measurement (Zurich, Switzerland, August 16-18, 2004), 2004; :1-2	2004	Publication	Respiratory diseases
Characterization of Diesel Particulate Matter (DPM) and Potential Health Effects Associated with Exposure to the DPM in Underground Mines Bugarski-AD; Gautam-M | In: Proceedings of the Mining Diesel Emissions Conference (Markham, Ontario, Canada)	2000	Publication	Respiratory diseases
Diesel Exhaust Control Technology: a Review Schnakenberg-GH; Bugarski-AD | In: Proceedings of the Mining Diesel Emissions Conference (Markham, Ontario, Canada)	2001	Publication	Respiratory diseases
Effects of Alternative Fuels on Concentrations of Nanometer and Ultrafine Particles in Underground Mine Bugarski-AD; Mischler-S; Schnakenberg-GH Jr | In: Proceedings of the Ninth ETH Conference on Combustion-Generated Nanoparticles (Aug. 15-17, 2005; Zurich, Switzerland)	2005	Publication	Respiratory diseases
Estimate of Technically Feasible DPM Levels for Underground Metal and Nonmetal Mines Schnakenberg-GH Jr | Min Eng, 53(9), Sep 2001:45-51	2001	Publication	Respiratory diseases
Evaluation of Diesel Particulate Filter Systems and Biodiesel Blends in an Underground Mine Bugarski-A; Schnakenberg-GH Jr; Noll-JD; Mischler-S; Crum-MW; Anderson-R | SME preprint 04-24. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004; :1-13	2004	Publication	Respiratory diseases
Evaluation of Diesel Particulate Filter Systems and Biodiesel Blends in an Underground Mine Bugarski-A; Schnakenberg-GH Jr; Noll-JD; Mischler-S; Crum-MW; Anderson-R | Trans Soc Min Metal Explor. Vol 318. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :27-35	2005	Publication	Respiratory diseases
Field Evaluation of Diesel Particulate Filters: Size-Selective Measurements of Aerosols in Mine Air and Engine Exhaust Bugarski-AD; Schnakenberg-GH Jr | In: Proceedings of the Mining Diesel Emissions Conference (Markham, Ontario, Canada)	2001	Publication	Respiratory diseases
Metal and Nonmetal Diesel Particulate Filter Selection Guide Schnakenberg-GH; Bugarski-AD; Angel-J; Saseen-G | Web document, http://www.msha.gov/nioshmnmfilterselectionguide/dpmfilterguide.htm	2005	Web document	Respiratory diseases
Review of Technology Available to the Underground Mining Industry for Control of Diesel Emissions Schnakenberg-GH Jr; Bugarski-AD | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2002-154, Information Circular 9462, 2002 Aug :1-51	2002	Publication	Respiratory diseases
Testing Diesel Emission Control Techniques Schnakenberg-GH Jr; Bugarski-AD | In: Proceedings of the Diesel Particulate in Mining Conference (Yeppoon, Queensland, Australia)	2004	Publication	Respiratory diseases
Testing of Diesel Emissions Control Technologies in Isolated Zone Bugarski-AD; Schnakenberg-GH Jr | In: Proceedings of the Mining Diesel Emissions Conference (Markham, Ontario, Canada)	2003	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
The Effectiveness of Selected Technologies in Controlling Diesel Emissions in an Underground Mine: Isolated Zone Study at Stillwater Mining Company's Nye Mine Bugarski-AD; Schnakenberg-GH; Noll-JD; Mischler-S; Patts-L; Hummer-J, et al. | Final report to Metal/Nonmetal Diesel Partnership, Jan 5, 2004, http://www.msha.gov/01-995/dpmdocs/stillwater.pdf	2004	Publication	Respiratory diseases
Workshop on Diesel Emissions Control Technologies in Coal Mines NIOSH | NIOSH-sponsored workshop, Louisville, KY (July 30, 2003)	2003	Workshop, Seminar, or OIB	Respiratory diseases
Workshop on Diesel Emissions Control Technologies in Metal/Nonmetal Mines NIOSH | NIOSH-sponsored workshop, Cincinnati, OH (February 27, 2003), Salt Lake City, UT (March 4, 2003)	2003	Workshop, Seminar, or OIB	Respiratory diseases

Strategic Program Outcome for Hearing Loss

Preventing Noise-induced Hearing Loss

Noise-induced hearing loss (NIHL) is the most common job-related illness in the United States today. NIHL is a top priority area in the National Occupational Research Agenda (NORA). It is especially common among miners. A NIOSH analysis of more than 60,000 audiograms showed that by age 51 about 90% of the coal miners and 49% of metal/nonmetal miners had a hearing impairment. By contrast, only 10% of the nonoccupational noise-exposed population had a hearing impairment by age 51. A 2005 analysis of changes in noise exposure showed that the renewed emphasis on hearing loss prevention has already had a substantial impact. There has been a 40% reduction in the average coal miner´s noise dose from 1997 to 2003. The rate of decline in exposures increased around 2000 when a new federal noise regulation took effect. Around the same time, our Hearing Loss Prevention Branch became fully staffed. The program is playing a major role in reducing NIHL in the U.S. mining industry.

When NIHL became a prominent mining health issue in the late 1990s, a new noise rule was passed in 1999 (30 CFR 62) to be enforced by the Mine Safety and Health Administration. Before 1998, there were fewer than three employees in the Mining Program working on noise issues. The Mining Program quickly increased its hearing loss prevention staff and has had more than 20 employees working on the problem every year since 2001. It now has core expertise in a variety of physical and social sciences so that it can fully support the other partners. These include industry groups, labor organizations, equipment manufacturers, and the mine workers themselves.

The Hearing Loss Prevention Program is following a two-phase strategy for maximum impact on the national hearing loss problem. In the first phase, the program provided scientific input to the new regulatory and voluntary industry efforts to curb NIHL. During this phase, the program established its scientific credibility as the best source for unbiased information about effective interventions. In the second phase, the program began generating proven techniques that would directly affect noise exposures and subsequent hearing loss.

Phase 2 is now well underway. Initially, this involved field tests of effective engineering controls and worker empowerment techniques that had proven effective in controlled settings. For instance, noise reduction coatings for a continuous mining machine conveyor have proven to be effective in lab and field trials. Also, NIOSH testing facilities identified that drilling systems originally developed to control dust also have a significant noise reduction benefit. On the behavioral side of prevention, a hearing loss simulator was developed to motivate workers to take a more active role in protecting their own hearing. These and other interventions are being promoted and disseminated to all applicable sectors of the industry and workforce through technical communication and social marketing. The impact of these and other successful interventions will be followed through long-term evaluations to confirm that workers are being exposed to less noise and that fewer of them will develop a hearing loss, thereby enhancing the quality of life of the nation´s miners.

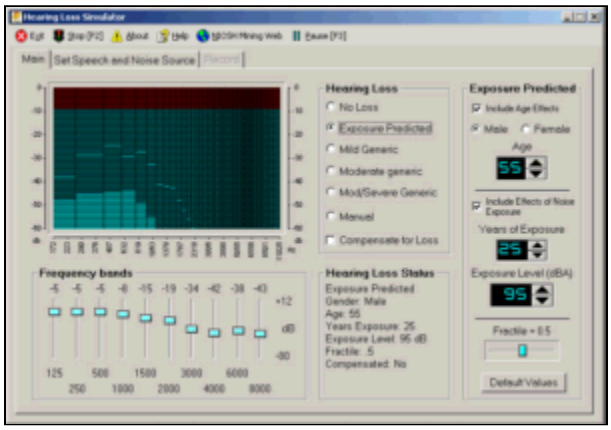
Intermediate Outcomes

- Motivating Prevention Behaviors with the NIOSH Hearing Loss Simulator
- Noise Reduction of Roof Bolting Machines Using Wet and Mist Drilling
- Reducing Noise on Continuous Mining Machines Using Coated Flight Bars

Intermediate Outcome related to Preventing Noise-induced Hearing Loss

Motivating Prevention Behaviors with the NIOSH Hearing Loss Simulator

Description of Problem



Screen shot of the Hearing Loss Simulator

Virtually every strategy for preventing hearing loss requires significant human effort. Engineering controls must be developed, implemented, and maintained. Administrative controls have to be designed, then adopted by workers who may have to adopt unfamiliar ways of working. Hearing protectors need to be provided and worn correctly. When these human efforts fall short, workers can receive hazardous noise exposures. For instance, even when hearing protectors are required, usage rates at or below 50% are typically reported. Operators of noisy equipment often leave their cab doors open, which increases their noise exposure by 9 decibels or more. These and other examples of inadequate prevention show a need for improved awareness and motivation.

Research and Development Activities

A NIOSH team developed the Hearing Loss Simulator to demonstrate that hearing loss is both a likely and severe consequence of noise exposure. The simulator is a Windows-based computer program that allows a trainer or user to "dial in" varying amounts of noise exposure to demonstrate the predicted damage to hearing. The predictions are based on the empirically validated models contained in the ANSI (American National Standards Institute) S3.44 standard. The software shows a graph of the frequencies or pitches most affected by noise. The graph shows the typical "notch" in the high frequencies for a noise-damaged worker. More importantly, the simulator provides an auditory demo of noise-induced hearing loss (NIHL). It contains prerecorded spoken messages to which the trainer can add background noises. These include a variety of mining, construction, and shop machinery. The noise makes the spoken message harder to understand. This further emphasizes the severity of NIHL. Trainees are usually workers, but can also be family members or managers who need to understand the effects of hazardous noise. By leading trainees through a series of scenarios, the simulator shows how NIHL can greatly affect communication, recognition of safety signals, and quality of life. A team of NIOSH behavioral scientists and software designers guided the simulator's development from an early prototype to a full-featured software package containing supporting documentation and training guidelines. The simulator was very successful when evaluated by coal miners, quarry workers, and technical support staff. For instance, 58 miners in a reaction study gave very positive responses to the simulator as a training tool. An evaluation of attitude and knowledge change for 89 miners and support staff showed significant increases in knowledge of hearing loss prevention and in intentions to take more effective action to preserve their hearing.

R&D Outputs and Transfer Activities

After these evaluations, NIOSH released the simulator to the public on CD-ROM. A distribution and tracking system was set up in October 2004. The simulator is also being distributed through the NIOSH website. Project staff are doing demos for health and safety practitioners throughout the United States in conjunction with the Noise Partnership and other industry and labor organizations.

Description of Intermediate Outcome

The simulator is being used as a training and motivational tool for preventing NIHL by stakeholders throughout the world. More than 300 requests for the simulator on CD-ROM have been received from stakeholders across the United States and other countries, including Mexico, Israel, Indonesia, and Canada. These include university audiology departments, state safety and health agencies, company training offices, independent industrial hygiene trainers, and military installations. In addition:

- Lee Hager of Sonomax (a producer of hearing protectors and a member of the National Hearing Conservation Association) has been using the simulator in training seminars. His audience consists mainly of audiologists, industrial hygienists, and occupational hearing conservationists. Seminar attendees have since requested the simulator for use in their own training and clinical practices.
- The simulator is a required component of a doctoral level hearing conservation course at Central Michigan University.
- The Better Hearing Institute has requested access to the simulator as part of its on-line hearing loss training materials at www.betterhearing.org. The institute is a not-for-profit organization that disseminates hearing loss prevention and treatment information to the general public.
- The Mine Safety and Health Administration (MSHA) is including the simulator in its workshops and seminars on hearing loss prevention for mine inspectors, miners, and technical support staff. The agency is also adding it to its catalog of training products.
- John Langton, the Deputy Administrator for Coal Mine Safety and Health for MSHA, recognized the simulator in his address to the Mining Hearing Loss Prevention Workshop in Charleston, WV, on June 21, 2005. He stated, "Today, tools such as...NIOSH's hearing loss simulator and MSHA's noise control guides are examples of valuable resources."
- Timothy Swisher of Employee Health, Inc. (recently named as the second most active provider of certification training for occupational hearing conservationists), is using the simulator in his popular certification classes.
- State agencies in Arizona, California, Colorado, Illinois, Missouri, New Hampshire, and Pennsylvania have asked to use the simulator.
- The Joseph A. Holmes Safety Association, the largest and oldest mining safety and health organization in the United States with more than 4,000 chapters, devoted a page on its website promoting the simulator in March 2005. The page had been accessed 749 times as of August 4, 2005.

- Rob Brauch of Larson Davis, Inc. (a leading manufacturer of noise control instruments), requested the simulator. He stated, "I present at many safety and health conferences and professional development courses around the world and would like to use this very effective tool to raise the awareness of the attendees about the effects of hearing loss."
- The simulator was featured in an article in the May 2005 issue of American Longwall Magazine. The article, entitled "NIOSH Simulator Music to the Ears," highlighted the simulator's usefulness in motivating hearing loss prevention and provided information on how to obtain a free copy.

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
Communicating the Same Message with Different Media: An Example from Hearing Loss Prevention Randolph-RF; Kohler-JL; Byrne-DC | In: Peters R, ed. Strategies for Improving Miners' Training. Pittsburgh, PA, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2002-156, Information Circular 9463, 2002 Sep :45-54	2002	Publication	Hearing loss; Surveillance and training
What Does a Hearing Loss Sound Like? NIOSH | Web document, www.cdc.gov/niosh/mining/topics/hearingloss/hlsoundslike.htm	2005	Web document	Hearing loss
Hearing Loss Simulator (HLSim) NIOSH | Version 2.2.0.26; Windows software; CD-ROM and downloadable (http://www.cdc.gov/niosh/mining/products/educationalsoftware.htm)	2004	Software	Hearing loss
Mining Hearing Loss Prevention Workshop NIOSH | Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss

Intermediate Outcome related to Preventing Noise-induced Hearing Loss

Noise Reduction of Roof Bolting Machines Using Wet and Mist Drilling

Description of Problem

Mist system on a roof bolting machine

Adding water to a drilling process on a coal mine roof bolting machine can reduce the drilling noise. However, it can lead to other problems, such as wet and slippery mine floors. It can also create an uncomfortable work environment for the drillers who are exposed to the water coming out of the drill holes. Coal noise data for 2000-2003 from the Mine Safety and Health Administration (MSHA) show that roof bolting machine operators are the second most common type of underground coal equipment operator whose noise dose exceeds 100%. Further, MSHA Program Information Bulletin P04-18 states that wet drilling (where compatible with the geology and mining method) is a technically and administratively achievable engineering control to reduce a miner's noise exposure and that mist drilling offers promise in reducing overexposure. Roof bolting machines are used in underground coal mines to drill vertical holes in the roof of the mine and then insert 3 foot to 8 foot bolts into the holes. This helps secure the mine roof and prevent dangerous roof falls. Drilling into hard rock in a confined space generally results in significant noise exposure for the drill operators. There is a need to evaluate the benefits of wet drilling on roof bolting machines and to evaluate mist drilling, which requires much less water than conventional wet drilling, but may, if properly used, give the same benefits in reducing noise.

Research and Development Activities

The NIOSH Pittsburgh Research Laboratory has the facilities and personnel to evaluate engineering controls via sound power level testing. NIOSH has documented that, given similar drilling configurations and drilling media, wet and mist drilling processes produce less noise than similar tests done under vacuum conditions. This is most apparent in the one-third octave band center frequencies of 1,000 Hz or greater. The water damps noise in these frequency bands, reducing the sound power level emission. NIOSH has been testing various wet and mist drilling systems in its acoustic test chamber to optimize and evaluate these drilling technologies. As the technologies are optimized for given mining conditions, they are then tested at mine field sites to confirm the findings in the real-world environment.

R&D Outputs and Transfer Activities

Results have been disseminated to the public via a conference paper entitled "A Sound Power Level Study of a Roof Bolter." NIOSH has also been transferring the research findings to labor, industry, equipment manufacturers, and MSHA through meetings of the Coal Mine Noise Partnership and through a partnership workshop designed to make the industry aware of various engineering noise controls. In addition, NIOSH has worked closely with equipment manufacturers to ensure ready acceptance of the findings.

Description of Intermediate Outcome

When compatible with mining conditions, wet drilling is generally an effective engineering control to reduce noise exposure to roof bolting machine operators. NIOSH research has shown that the sound pressure level at the operator position attributable to the roof bolting machine is almost always reduced when wet drilling is used. Research has also shown that wet drilling enhances performance, i.e., penetration rate. Depending on the compressive strength of the drill media, lab and field testing suggest reductions of 2 to 7 dB(A) at the bolter operator's position. Roof bolting machines equipped for wet drilling are currently available from J.H. Fletcher & Co., the leading U.S. manufacturer of roof bolting machines. Fletcher has worked closely with NIOSH in developing wet drilling technology.

Mist systems, developed by Joy Mining Machinery (U.S. Patent #5,875,858, Mist System - Joy Mining Machinery) and tested by NIOSH as a retrofit for J.H. Fletcher & Co. roof bolting machines, are currently in use in several mines. The big advantage to the mist drilling system is that it has the same benefit as wet drilling, but uses much less water. This creates a better work environment for the miner and puts less water on the mine floor. In mines where wet drilling creates a problem, mist drilling offers a viable alternative.

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
A Sound Power Level Study of a Roof Bolter Peterson-JS; Kovalchik-PG; Matetic-RJ | SME Preprint No. 05-72, 2005 SME Conference, Salt Lake City, Utah, 2005; :8 pp	2005	Publication	Hearing loss
Mist System - Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62) NIOSH | Information Bulletin P04-18, 2005 (http://www.msha.gov/regs/complian/PIB/2004/pib04-18.pdf)	2005	Publication (guidelines)	Hearing loss
Wet Drilling - Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62) NIOSH | Information Bulletin P04-18, 2005 (http://www.msha.gov/regs/complian/PIB/2004/pib04-18.pdf)	2005	Publication (guidelines)	Hearing loss
Mining Hearing Loss Prevention Workshop NIOSH | Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss

Intermediate Outcome related to Preventing Noise-induced Hearing Loss

Reducing Noise on Continuous Mining Machines Using Coated Flight Bars

Description of Problem

Coated flight bars on a continuous mining machine

Data from the Mine Safety and Health Administration (MSHA) show that the continuous mining machine is first among all equipment in underground coal mining whose operators exceed 100% noise dosage. Continuous miners are large underground machines that cut coal at the working face of the mine. They gather up the cut coal and transport it via an onboard conveyor to the back of the machine. Here, it is loaded onto either another conveyor or a piece of mining equipment designed to carry the coal away from the working face. One of the main noise sources on a continuous mining machine is the onboard conveyor. This consists of a chain with flight bars that drags the coal along the base of the conveyor system. The metal chain and flight bars in contact with the metal base and the coal itself contribute greatly to the noise exposure of workers at the face. Continuous miner operators stand near the chain conveyor, especially at the back of the machine, and receive a great part of their noise exposure from the conveyor.

Research and Development Activities

NIOSH addressed this issue by developing a chain conveyor with coated flights as a noise control for reducing the sound power emissions of continuous mining machines. By coating the flight bars with a heavy-duty, highly durable plastic, the metal-to-metal and metal-to-coal contact is reduced. This reduces the noise levels. NIOSH designed, developed, and lab tested this control in partnership with labor (United Mine Workers of America), industry (National Mining Association, Bituminous Coal Operators' Association), manufacturers (Joy Mining Machinery, C.U.E., Inc.), and Mine Safety and Health Administration (MSHA) stakeholders. The coated flight bars have proven to withstand the harsh mining environment and achieve a total noise exposure reduction of 7 dB(A) at the operator position. In many cases, this reduction can bring the machine operator into compliance with current regulations.

R&D Outputs and Transfer Activities

The coated flight bar chain conveyor is currently being made and sold by Joy Manufacturing, Inc., which produces over 80% of the continuous mining machines in the United States. Also, this control is now being used in at least two U.S. operating coal mines and a mine in South Africa. Currently, NIOSH is conducting a study to show how effective this control is in reducing the noise exposure of continuous mining machine operators under a variety of conditions. NIOSH has transferred the findings of this research to interested industry parties through journal articles,

conference proceedings, conference presentations, industry/labor workshops, and industry/labor/NIOSH partnership meetings. Technology transfer efforts such as workshops, conference presentations, and journal articles are selected based on their ability to reach the target audience for the research.

Description of Intermediate Outcome

The acceptance of this technology as an effective noise control by members the Coal Mining Noise Partnership (United Mine Workers of America, MSHA, National Mining Association, and the Bituminous Coal Operators' Association) is evidence of the potential impact of this control. The Coal Partnership represents the workers, the mining companies, the mining machine manufacturers, and the regulatory/enforcement arm of the government for coal mining. Several mine operators at two coal mine sites have stated that they now observe a clear reduction in the noise level of the continuous mining machine. Also, the mine workers have noted that the control is easy to implement and very durable. MSHA cited this as a "promising" noise control in Program Information Bulletin P04-18, "Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62)."

Outputs

5 Outputs

Title	Year	Output Type	Strategic Goal
A Noise Control for Continuous Miners Kovalchik-PG; Johnson-M; Burdisso-R; Duda-F; Durr-M | Tenth International Meeting on Low-Frequency Noise and Vibration and its Control (Sept. 11-13, 2002; York, United Kingdom)	2002	Publication	Hearing loss
Coated Flight Bars - Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62) NIOSH | Information Bulletin P04-18, 2005 (http://www.msha.gov/regs/complian/PIB/2004/pib04-18.pdf)	2005	Publication (guidelines)	Hearing loss
Estimated Sound Power Radiated by Surfaces on a Continuous Miner Tail Section Using Vibration Measurements Yantek-DS | NOISE-CON 2003. Ames, IA: Institute of Noise Control Engineering of the USA, 2003 Jun; :1-9	2003	Publication	Hearing loss
Evaluation of Engineering Noise Controls for a Continuous Miner Conveyer System Durr-TM; Kovalchik-P; Kwait-E | NOISE-CON. Ames, IA: Institute of Noise Control Engineering of the USA, 2003 Jun; :1-11	2003	Publication	Hearing loss
Mining Hearing Loss Prevention Workshop NIOSH | Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss

Strategic Program Outcome for Cumulative Injuries

Preventing Musculoskeletal Disorders

Mining is one of the most physically demanding occupations. It is also one of the most dangerous in terms of exposure to ergonomic hazards. Musculoskeletal disorders (MSDs) resulting from repetitive manual work have long been identified as a significant and costly problem for the mining industry. Strain and sprain injuries account for 24.0% and 25.2%, respectively, of all reported injuries for underground coal mining. They account for 19.4% and 20.4%, respectively, of all injuries for underground metal/nonmetal mining. In 2003, the Mine Safety and Health Administration (MSHA) reported that 44% of all illnesses were joint, tendon, or muscle inflammation. Using a new process integration and interventions development approach in mining, NIOSH contributed to a 34% overall reduction in lost workdays due to repetitive-type injuries during 1998-2004. This approach focuses on incorporating the ergonomics process in existing safety and health programs of the mining companies and empowering the workers to proactively develop injury prevention solutions to their tasks.

Although the need for intervention and prevention is great, the underground mine environment poses unique barriers to implementing many standard ergonomic "fixes." The mining workplace is a very dynamic work environment. This dynamic nature requires that workers be made aware of risk factors and take early actions to reduce their injury risk. However, mining companies rarely spend the resources to educate workers on ergonomic interventions despite recent evidence that ergonomic considerations can have significant impact in reducing the risk of both MSDs and traumatic injuries. This impact is documented in other industries that voluntarily implemented interventions despite lack of any established ergonomic regulations, standards, and methodology prescribing how that science should be applied in a workplace.

Recent major accomplishments pertain to (1) whole-body vibration and (2) development of ergonomic processes through partnerships with mines. Previous studies have shown that operators of heavy mobile equipment are afflicted by musculoskeletal injuries of the arms, shoulders, neck, and lower back. From this review, it is shown that whole-body vibration (WBV) and the postural requirements of work (both static and awkward postures) are important risk factors that contribute to MSDs among equipment operators. Despite this, very little research has been done to systematically characterize the exposure to these ergonomic hazards. Quantifying vibration and postural requirements in practical settings is needed for a better understanding of the exposure levels present in different equipment while performing various tasks. Furthermore, it is important to evaluate postural instability caused by exposure to WBV and evaluate the availability of proper egress for preventing falls among operators of mobile equipment. As such, our research evaluates exposure to WBV, awkward posture, postural stability, and improper egress from equipment among operators of mobile equipment.

For an ergonomics process to be accepted and effective, it requires working with mining companies, associations, and regulatory agencies (MSHA and the Occupational Safety and Health Administration (OSHA)) in a holistic approach. Science-based education and interventions have led to a rising awareness among mining companies of the benefits of a proactive process addressing MSD risk factors. For example, successful education of 280 management and labor employees and implementation of a proactive ergonomics program at Bridger Coal Co. have resulted in reduced injuries and more than 22 ergonomic interventions in use at the company´s mine. Using results from the Bridger experience, researchers have been able to educate mines such as Badger Mining, Vulcan

Materials, Specialty Minerals, Unimin, and Morton Salt in the importance of the abovementioned new approach, which relies on an employee participation process to implement interventions that promote their health and safety at work. This success has led to the request by many mining companies (e.g., U.S. Borax, U.S. Silica, Consol) and organizations (e.g., Industrial Minerals Association (IMA), National Stone, Sand & Gravel Association (NSSGA), United Mine Workers of America (UMWA)) for similar guidance from NIOSH. Currently, three aggregate companies (Vulcan Materials, Hansen, and Luckstone) and two industrial sand companies (Unimin and Badger Mining), as well as two of the largest mining associations (IMA and NSSGA), have joined our effort to develop methods and education that ensure successful integration of ergonomics into their current safety and health programs.

Although several interventions have been developed in the past, the documentation of their effectiveness and use has not been recorded. A new approach of thorough documentation and measurement of usability and effectiveness is our focus as the programs grows over the next decade. NIOSH is attempting to address the lack of ergonomics education, process implementation, surveillance systems, and science-based interventions in mining. In that effort, a significant investment has been made to grow and focus MSD prevention research within the NIOSH Mining Program during recent years. The new MSD Prevention Team is composed of certified professional ergonomists, industrial and mining engineers, training specialists, physiologists, bioengineers, and engineering technicians. A multidisciplinary approach to bringing safety, health, and productivity is afforded through this diverse team and through cooperation with other Mining Program teams, such as training, machine safety, and electrical safety.

Our MSD prevention research has both field and lab components. Field research determines priority problems through direct observations and physical measurements. The physical requirements of any job are not easily measured in the workplace. Lab experiments provide opportunities to study MSD risk factors in a controlled environment. The results add to the science and knowledge base of ergonomics. Recently, a NIOSH researcher conducted studies that defined the physiological demand of performing lifting tasks while the back is in flexion. This study showed that the angle of flexion has a significant effect on resultant low-back pain and injury. Considering the restricted postures used by miners while doing their jobs, the impact of this study is far-reaching. This research directly relates to the importance of the design of physical tasks performed in mining and has contributed to a preliminary assessment tool designed to determine the prevalence of low-back pain as it relates to typical mining tasks.

Other functions of the lab studies are to simulate mining tasks and equipment, determine physical effort, and test possible interventions for better job and equipment design. For example, NIOSH developed an improved low-seam shuttle car seat that reduces worker exposure to damaging jarring and jolting. The seat is now available from Joy Mining Machinery, the largest equipment manufacturer of shuttle cars, and is being ordered by mining companies for both new and retrofit orders. Researchers examine the effects of the mining environment, workforce age, and equipment and tool design on the jobs performed by mine workers. Currently, experiments on ingress/egress of equipment, scaling bar, and roof bolter screening studies are being done in our state-of-the-art labs. These include three physical capabilities labs (strength, vibration, and motion analysis) and a human performance research mine, which simulates an underground mining environment. These new labs are equipped with current technologies, including telemetric electromyography, an infrared motion analysis system, a lumbar motion monitor, force plates, and goniometers. Major equipment

manufacturers (Joy, Jeffrey, and Voest-Alpine), universities (Purdue University, University of Pittsburgh, University of Wisconsin, and University of Cincinnati), and mining associations (IMA, NSSGA, and UMWA) are partners in the studies. Interventions are developed, tested, then taken to the field. This comprehensive methodology allows researchers to prioritize, study, and solve the most pressing and costly health and safety problems in the mining industry. Science-based interventions are then shared with the mining industry. The main goal is to reduce risk factors with a high probability of leading to MSDs and lost work.

Because the team is small compared to the required resources for directly addressing the needs of each mining company, leveraging large mining associations and partnering with mine companies, universities, and government agencies will help to integrate the ergonomics process into their existing health and safety programs. Our proactive approach to reduce risk factors on the job instead of waiting for an injury to occur is catching on fast in the mining industry. In view of the current predominantly older workforce, the mining industry is in a unique position to make use of their experience and knowledge to help design better mining methods, tools, equipment, and processes for a new generation of miners. The intermediate- and long-term impacts of our MSD injury prevention research is expected to be visible and significant. As the costs of MSD injuries continue to rise, reduction of risk factors becomes critical to the effective and efficient use of the mining industry´s most valuable asset - its workforce.

Intermediate Outcomes

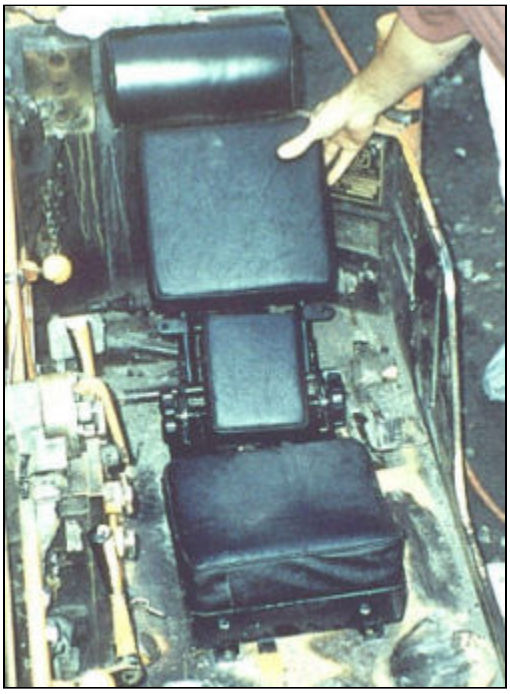
- Improved Seat Design for Low-Seam Shuttle Cars
- Reducing Work-related Musculoskeletal Disorders in Mining - Collaborations with Bridger Coal Company

Intermediate Outcome related to Preventing Musculoskeletal Disorders

Improved Seat Design for Low-Seam Shuttle Cars

Description of Problem

Research has shown that up to one-third of equipment operators in underground coal mines experience adverse levels of exposure to whole-body vibration (WBV). Major sources of WBV exposure are shuttle cars. Operators are exposed to vehicle jarring/jolting when the shuttle car travels over rough mine floor characterized by numerous bumps, ruts, and potholes. The problem is especially acute in low-seam coal mines, where seat suspension systems are hard to implement because of space restrictions.



Low seam shuttle car seat intervention for reducing jarring and jolting injuries

Research and Development Activities

NIOSH developed and tested an improved seat design for low-seam shuttle cars at cooperating mines in West Virginia and Kentucky. The seat accommodates a broader segment of the population because it is more adjustable and easier to use. It also features viscoelastic foam to reduce the risk of vehicle jolting and jarring injuries, as well as an adjustable lumbar pad needed to support the lower back while in a reclined seated position.

R&D Outputs and Transfer Activities

Joy Mining Machinery, Inc., has applied our research results for an improved seat design on low-seam shuttle car haulage. The enhanced seat design (use of viscoelastic foams and adjustable lumbar) became standard on all Joy 21SC shuttle cars as of August 2001.

Description of Intermediate Outcome

Joy Mining Machinery includes the improved seat design in its current product line. The company independently tested the new design and confirmed the results of the NIOSH study. Results from our field studies show that the vast majority of users prefer the new seat over traditional designs. The end users are pleased with the seats' ability to reduce jarring/jolting impact and to support their back and neck, as well as its adjustability. For the 21SC Model shuttle car, Joy Manufacturing has sold over 200 of the newly designed seats. They have also sold 60 replacement seats for existing 21SC Model shuttle cars in use. Approximately 150 new 10SC Model cars have been sold with the visoelastic foam padding and 100 replacement seats have been sold for the same model.

Outputs

7 Outputs

Title	Year	Output Type	Strategic Goal
Ergonomic and Existing Seat Designs Compared on Underground Mine Haulage Vehicles Mayton-A.J; Ambrose-DH; Jobes-CC; Kittusamy-NK | In: Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting (Denver, CO; Oct. 13-17, 2003). Santa Monica, CA: Human Factors and Ergonomics Society; :1256-1260	2003	Publication	Cumulative injuries; Traumatic injuries
Ergonomic Seat With Viscoelastic Foam Reduces Shock on Underground Mobile Equipment Mayton-AG; Gallagher-S; Merkel-R | In: B. Das; W. Karwoski, eds., Advances in Occupational Ergonomics and Safety II, IOS Press and Ohmsha, 1997 Jun; :177-180	1997	Publication	Cumulative injuries; Traumatic injuries
Ergonomic Seat With Viscoelastic Foam Reduces Shock on Underground Mobile Equipment Mayton-AG; Gallagher-S; Merkel-R | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin, 1998 Apr; :12-13	1998	Publication	Cumulative injuries; Traumatic injuries
Improved Seat Reduces Jarring/Jolting for Operators of Low-Coal Shuttle Cars Mayton-AG; Merkel-R; Gallagher-S | Mining Eng 51(12), 1999 Dec; :52-56	1999	Publication	Cumulative injuries; Traumatic injuries
Shock Reduction for Low-Coal Shuttle Car Operators Using Viscoelastic Seating Foam Mayton-A; Merkel-R; Gallagher-S | Society for Mining, Metallurgy, and Exploration Annual Meeting, SME preprint 98-44, Littleton, CO, Society for Mining, Metallurgy, and Exploration, Inc., 1998 Mar; :1-4	1998	Publication	Cumulative injuries; Traumatic injuries
Systematic Comparison of Different Seats on Shuttle Cars Used in Underground Coal Mines Kittusamy-NK; Mayton-AG; Jobes-CC; Ambrose-DH | Proceedings of the 32nd International Congress and Exposition on Noise Control Engineering, Jeju International Convention Center (Seogwipo, Korea; August 25-28, 2003)	2003	Publication	Cumulative injuries; Traumatic injuries
Technology News 459 - Ergonomic Seat Reduces Shock for Low-Seam Shuttle Car Operators Mayton-AG; Gallagher-S | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 459, 1997 May :1-2	1997	Publication	Cumulative injuries; Traumatic injuries

Intermediate Outcome related to Preventing Musculoskeletal Disorders

Reducing Work-related Musculoskeletal Disorders in Mining - Collaborations with Bridger Coal Company

Description of Problem

Work-related musculoskeletal disorders (MSDs) have long been identified as a significant and costly problem for the mining industry. These disorders result from exposure to MSD risk factors. Studies have shown that a sizable percentage of mine workers (at least 35%) were potentially exposed to overload conditions affecting the neck, back, forearms, arms, shoulders, fingers, and hands. The cumulative nature of MSDs suggests that older workers may be at greater risk since they have more years of exposure to physically demanding work. In addition, older workers often require a longer period of time to recover from injuries.

Intervention for reducing MSD in a dozer blade changing task at Bridger Coal

Research and Development Activities

Collaborative research with Bridger Coal Co. has led to the implementation of an ongoing, effective process to reduce exposure to work-related MSD risk factors. NIOSH's role is to guide and direct Bridger in customizing and implementing a sound ergonomics process that they can build upon and continue to benefit from for years to come. Bridger's ergonomics process has become a proactive model for other organizations to consider:

- How to integrate ergonomics into work processes to instill a proactive health and safety culture.
- How to actively encourage employee participation in reducing injury risk though science-based education and real-life applications.
- How to integrate ergonomic principles into specifications used for purchasing new equipment.

R&D Outputs and Transfer Activities

Collaborative research resulted in an organizational shift to a more proactive culture where reductions in risk factors for MSDs are the main dependent measures of safety and health success. NIOSH and Bridger personnel have coauthored publications and presentations designed to inform others about what was learned in applying ergonomics to a dynamic production process.

Description of Intermediate Outcome

Aided by NIOSH expertise, Bridger has changed its internal procedures with regard to assessing risk and examining work-related risk factors. PacifiCorp, Bridger's parent company, modified its risk assessment tools used across corporate sites to include work-related MSD risk factors.

Accordingly, Bridger has changed its internal procedures with regard to specifications and ergonomic considerations in purchasing new equipment. The company is also relying on an employee-based participative process to identify and implement ergonomic interventions that promote healthier work methods *before* injuries occur.

Bridger's ergonomics committee facilitated implementation of 22 interventions in 3 years. This resulted in reduced exposures to work-related MSD risk factors for several work tasks. About 4 years ago, Bridger began an effort to convert its surface mine to an underground operation. The ergonomics coordinator for the surface operations was assigned to apply the ergonomics process developed for the surface operation to the underground mine. Employee discomfort levels were assessed before and after (3 years) implementing the ergonomics process at the Jim Bridger Mine. The percentage of employees reporting discomfort decreased 15% over the 24- to 36-month timeframe. The specific body parts with decreased reports of discomfort included the neck, wrists, lower back, knees, ankles, and feet.

Outputs

11 Outputs

Title	Year	Output Type	Strategic Goal
Collaborative Ergonomics Field Research: An Assessment of Risk Factors at Four Mines Steiner-LJ; Bauer-ER; Cook-AH; Cornelius-KM; Gallagher-S; Rethi-LL; Rossi-EW; Turin-FC; Wiehagen-WJ | Min Eng 56(2), 2004; :41-48	2004	Publication	Cumulative injuries
Ergonomic Assessment of Musculoskeletal Risk Factors at Four Mine Sites: Underground Coal, Surface Copper, Surface Phosphate, and Underground Limestone Wiehagen-WJ; Turin-FC | NIOSH Publication No. 2004-159, Information Circular 9475, 2004 Aug :1-38	2004	Publication	Cumulative injuries
Ergonomic Issues in Mining Gallagher-S | In: Karwowski W, Marras WS, eds. The Occupational Ergonomics Handbook, Boca Raton, FL, CRC Press LLC, 1999; :1893-1915	1999	Publication	Cumulative injuries
Ergonomics Considerations for Reducing Cumulative Trauma Exposure in Underground Mining Cornelius-KM; Turin-FC | In: W. Karwowski, ed. International Encyclopedia of Ergonomics and Human Factors, 2001, Vol. III, London, United Kingdom, Taylor & Francis, Inc. 2001; :1497-1500	2001	Publication (guidelines)	Cumulative injuries
Initiating an Ergonomics Process at a Surface Coal Mine Unger-RL; Turin-FC; Wiehagen-WJ; Steiner-LJ; Cornelius-KM; Torma-Krajewski-J | In: Bockosh GR, Kohler JL, Langton JF, Novak T, McCarter MK, Biviano A, eds. Proceedings of the 33nd Annual Institute on Mining Health, Safety and Research (Aug 27-30, 2002; Roanoke, VA), Blacksburg, VA: Virginia Polytechnic Institute and State University, Department of Mining and Minerals Engineering, 2002; :39-47	2002	Publication (guidelines)	Cumulative injuries
Partnering for Successful Ergonomics: A Study of Musculoskeletal Disorders in Mining Steiner-LJ; James-P; Turin-FC | In: SME Annual Meeting (Feb 24-26, 2003; Cincinnati OH), SME preprint 03-118. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :1-5	2003	Publication	Cumulative injuries
Physical Strength Assessment in Ergonomics Gallagher-S; Moore-JS; Stobbe-TJ; McGlothlin-JD; Bhattacharya-A | In: Shell RL, Hall EL, eds. Handbook of Industrial Automation, New York, NY: Marcel Dekker, Inc., 2000; :797-827	2000	Publication	Cumulative injuries
Physical Strength Assessment in Ergonomics Gallagher-S; Moore-JS; Stobbe-TJ | American Industrial Hygiene Association 1998 :1-61	1998	Publication	Cumulative injuries
Recommendations for Reducing Mine Worker Cumulative Trauma Exposure Cornelius-KM; Turin-FC | In: Proceedings of the IIE Annual Research Conference. Norcross, GA: Institute of Industrial Engineers (CD-ROM), 2001	2001	Publication (guidelines)	Cumulative injuries
Using Ergonomics to Enhance Safe Production at a Surface Coal Mine: A Case Study With Powder Crews Wiehagen-W; Torma-Krajewski-J; Peterson-A; Turin-F; Unger-R | In: Proceedings of 2004 Joint Conference on Mine Safety and Health (May 23-28, 2004; Salt Lake City, UT)	2004	Publication	Cumulative injuries
What Works (and What Doesn't) in Mining Ergonomics Gallagher-S | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin Nov, 1999 Nov; :9-13	1999	Publication	Cumulative injuries

Strategic Program Outcome for Traumatic Injuries

Reducing Traumatic Injuries and Fatalities in Blasting

Over the past 25 years, the frequency of blasting-related injuries and fatalities at mining operations has dropped significantly. In 1978, 140 miners were killed or injured in U.S. blasting accidents. By 1998, this number had dropped to 22 and continued to decline to 7 in 2001. Factors contributing to increased blasting safety include the development of nonelectric initiation systems; the change from the use of cartridged explosives to bulk explosives; increased use of safer, non-nitroglycerine explosives; development of safer blasting practices; and an increase in the knowledge and professionalism of the average blaster. Industry, labor, and government all contributed to the improved safety record.

NIOSH conducted research to help eliminate injuries and fatalities resulting from blasting accidents. When high-detonation pressure (HDP-1) explosive boosters and Detaline initiation systems marketed by Explosives Technologies International (ETI) seemed to play a role in explosives accidents, the Mine Safety and Health Administration (MSHA) asked for technical assistance. Following a research project in which the accidents were simulated, NIOSH researchers identified the problem and advised the manufacturer and MSHA on how to modify the booster to make it safer.

During the 1990s there were a number of cases of carbon monoxide (CO) poisoning near blasting sites. Whether this type of accident had not occurred before the 1990s or whether it had occurred but had gone unrecognized is uncertain. The latter seems the more likely scenario. NIOSH became aware of the problem when a congressman asked for assistance in the investigation of a nonfatal CO poisoning incident in Dunmore, PA. As word of the incident and NIOSH assistance spread, requests came in from state and local officials who suspected that they might have cases of CO poisoning near blasting sites. NIOSH researchers became recognized as experts on the issue. Cases of CO poisoning near blast sites have essentially disappeared as NIOSH made blasters aware of the problem. Blasters now routinely place CO monitors in any structure at risk for CO infiltration.

The heavy equipment at all mining sites leads to the generation of quantities of waste motor oil. In past years, mines had no choice but to pay someone to dispose of this oil. Some in the industry realized that the waste motor oil could become a resource rather than a liability if it were used to make ammonium nitrate fuel oil (ANFO) blasting agent. MSHA regulations prohibited this practice because of concerns that contaminants in the oil could lead to the production of unusually sensitive, insensitive, or thermally unstable ANFO. MSHA would consider allowing mines to use the waste oil in explosives if this were approved on a case-by-case basis. Mines proposed procedures to use the waste oil in ANFO and asked for approval. There was no precedent for knowing which of these practices was safe. MSHA asked NIOSH to conduct research to evaluate the safety of waste oil-produced ANFO and help them develop safety guidelines for this practice. These guidelines were adopted by industry and are now used every time a mine uses waste oil in ANFO.

Mines in the Powder River Basin of Wyoming asked for NIOSH assistance when concerns arose about the orange or red product clouds rising from large-scale surface blasts. These blasts contained up to 8 million pounds of blasting agent. The orange to red color resulted from high concentrations of nitrogen dioxide (NO_2), a highly toxic gas, in the product cloud. NIOSH researchers met with mine safety personnel to discuss the problem and conducted in-house research to determine the

factors that lead to excessive NO_2. NIOSH advised the mines on the results of the research and recommended practices that might reduce NO_2 production. The mines and explosives suppliers adopted some of the recommendations and, in some cases, used them as the starting point for their own research to solve the problem.

NIOSH research has contributed to making blasting at mines safe and will continue to aid industry in maintaining this good safety record in the future.

Intermediate Outcomes

- Development of Guidelines for Reducing the Probability of Carbon Monoxide Poisonings Associated With Trench Blasting
- Development of Guidelines for the Safe Use of Waste Motor Oil in ANFO
- Modification of a High-Explosive Booster to Improve Safety
- Reduced NO_2 Production from Large-Scale Production Blasts at Surface Mines

Intermediate Outcome related to Reducing Traumatic Injuries and Fatalities in Blasting

Development of Guidelines for Reducing the Probability of Carbon Monoxide Poisonings Associated With Trench Blasting

Description of Problem

All explosives generate carbon monoxide (CO) to one degree or another depending on their oxygen balance. Since 1988, there have been 17 reported incidents in which explosive-generated CO moved through the ground and accumulated in a nearby underground enclosed space. As a result, there have been 30 suspected or medically verified CO poisonings and 1 fatality.

Researchers study data collected from an experimenal explosive shot at PRL

Research and Development Activities

NIOSH expertise was called upon to identify the root cause of the CO poisoning among several likely proposed scenarios. NIOSH researchers evaluated the evidence and identified poor-quality explosive formulation as a major contributing factor. During the study, NIOSH researchers also recognized a need to better educate blasters and workers as to the hazards of CO and to develop guidelines to reduce the probability of future events when blasting near occupied dwellings. Subsequently, NIOSH researchers have been called upon to assist in other explosives and mining-related investigations involving toxic fumes. These include gas migration incidents in Dunmore, PA; Kittanning, PA; Lake Mills, WI; Derry, PA; Bristow, VA; and Amherst, NY.

R&D Outputs and Transfer Activities

NIOSH published papers to alert the public and industry about the possibility of CO poisoning due to nearby blasting. NIOSH researchers have also given presentations on this topic at national conferences for the International Society of Explosives Engineers (ISEE), local ISEE chapter meetings, the Penn State Drilling and Blasting Conference, and drilling and blasting seminars sponsored by the Mine Safety and Health Administration. For each gas migration incident, NIOSH researchers met with local and state officials to educate and advise them. For example, one explosives researcher worked with the New York State Department of Transportation (NYSDOT) in Amherst, NY. In this incident, blasting for the installation of new sewer lines had produced CO that migrated into nearby homes and businesses. This caused home CO monitors to alarm. Researchers recommended a change in explosive and advised NYSDOT on CO monitoring techniques. They

also assisted NYSDOT in developing better safety requirements for blasters and steps to take to mitigate the effects of CO when detected in nearby homes. This was incorporated into the blast plan. NYSDOT also asked NIOSH to comment on the blast plan revisions, which included mitigation techniques to use in the event of high CO measured in nearby structures.

Description of Intermediate Outcome

In 2001, NIOSH *Technology News* No. 488 advised blasters to place CO monitors in basements of homes and businesses near blasting sites. Many blasters now routinely employ this practice. Since 2001 there have been no reported blasting-related CO poisonings. In the two most recent known incidents of CO migrating from blasts, home CO monitors alerted residents before they became sick. Blasters are now aware of the importance of using good-quality explosives to minimize generation of CO when blasting near occupied dwellings.

Outputs

8 Outputs

Title	Year	Output Type	Strategic Goal
Blasting-Related Carbon Monoxide Migration Incident in Bristow, Virginia Harris-ML; Rowland-JH; Mainiero-RJ | In: Proceedings of the 30th Annual Conference on Explosives and Blasting Technique (New Orleans, LA, Feb. 1-4, 2004). Vol. 2. Cleveland, OH: International Society of Explosives Engineers; :319-327	2004	Publication	Traumatic injuries
CO Migration from Trench Blasting in Amherst, New York Harris-ML; Mainiero-RJ | In: Proceedings of the 30th Annual Conference on Explosives and Blasting Technique (New Orleans, LA, Feb. 1-4, 2004). Vol. 2. Cleveland, OH: International Society of Explosives Engineers; :25-39	2004	Publication	Traumatic injuries
Fugitive Carbon-Based Gases: Blasting Related or Not Eltschlager-KK; Harris-ML; Baldassare-F | In: Proceedings of the 30th Annual Conference on Explosives and Blasting Technique (New Orleans, LA, Feb. 1-4, 2004). Vol. 1. Cleveland, OH: International Society of Explosives Engineers; :409-418	2004	Publication	Traumatic injuries
Hazard Evaluation and Technical Assistance Report, HETA-98-0020, Carbon Monoxide Intoxication and Death in a Newly Constructed Sewer Manhole NIOSH | U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 98-0020; :1-22	1997	Publication	Traumatic injuries
NIOSH Hazard ID - Carbon Monoxide Poisoning and Death After the Use of Explosives in a Sewer Construction Project NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication 98-122, 1998 Mar	1998	Publication	Traumatic injuries
Protecting Workers From Toxic Fumes Generated by Explosives Mainiero-RJ | Tunnel Business Magazine, 1999 Dec; :15	1999	Publication	Traumatic injuries
Technology News 488 - Migration of Blasting Fumes into a Western Pennsylvania Home NIOSH | Pittsburgh, PA: US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 488, May 2001; :1-4	2001	Publication	Traumatic injuries
Toxic Fume Comparison of a Few Explosives Used in Trench Blasting Harris-ML; Sapko-MJ; Mainiero-RJ | In: Proceedings of the 29th Annual Conference on Explosives and Blasting Technique (Nashville, TN, Feb. 2-5, 2003). Vol. 2. Cleveland, OH: International Society of Explosives Engineers; :319-336	2003	Publication	Traumatic injuries

Intermediate Outcome related to Reducing Traumatic Injuries and Fatalities in Blasting

Development of Guidelines for the Safe Use of Waste Motor Oil in ANFO

Description of Problem

During the mid-1990s, several mines had asked the Mine Safety and Health Administration (MSHA) if they could dispose of waste motor oil from their heavy equipment by using it to make ammonium nitrate fuel oil (ANFO) blasting agent. MSHA regulations prohibited this practice because it was not known if it was safe.

Blasting agent, combined with waste oil, being loaded into boreholes

Research and Development Activities

MSHA asked for NIOSH assistance in determining whether this practice was safe and in developing a set of criteria that mines would have to follow to employ this practice safely. The Pittsburgh Research Laboratory conducted research to determine the temperature at which waste oil became too viscous to properly coat ammonium nitrate prills, developed a field test that blasters could use to ensure that their waste oil was properly mixing with ammonium nitrate, and evaluated the thermal stability of ANFO produced with waste oil. At MSHA's request, NIOSH assisted mines in developing safe procedures for the use of waste oil in ANFO.

R&D Outputs and Transfer Activities

NIOSH researchers and MSHA personnel developed a set of safe practices for the use of waste oil in explosives. MSHA required that any mine using waste oil in explosives had to follow these practices. Through publications and presentations at conferences, NIOSH informed blasters of these safe practices.

Description of Intermediate Outcome

The use of waste motor oil in ANFO has now become an accepted industry practice. The NIOSH-developed guidelines were adopted by the Institute of Makers of Explosives. Mines save the cost of disposal of waste motor oil, decrease their need for fuel oil, and turn waste motor oil into a usable resource rather than a waste product that requires disposal.

Outputs

2 Outputs

Title	Year	Output Type	Strategic Goal
Low Temperature Limits for Mixing Recycled Oil, Diesel Fuel, and Ammonium Nitrate to Make ANFO-Type Blasting Agents Ruhe-TC; Bajpayee-TS | In: Proceedings of the 22nd Annual Conference on Explosives and Blasting Technique (Orlando, FL, Feb. 4-8, 1996). Vol. 2. Cleveland, OH: International Society of Explosives Engineers, 1996; :232-243	1996	Publication	Traumatic injuries
Thermal Stability of ANFO Made with Recycled Oil Ruhe-TC; Bajpayee-TS | In: Proceedings of the 25th Annual Conference on Explosives and Blasting Technique (Nashville, TN, Feb. 7-10, 1999). Vol. 2. Cleveland, OH: International Society of Explosives Engineers, 1999 Feb; :263-271	1999	Publication	Traumatic injuries

Intermediate Outcome related to Reducing Traumatic Injuries and Fatalities in Blasting

Modification of a High-Explosive Booster to Improve Safety

Description of Problem

During 1996-1999, there were three blasting accidents involving a single type of detonator and booster. In one case, the detonator and booster detonated in the blaster's hands during assembly. The other two cases involved booster/detonator assemblies that initiated by impact at the bottom of a blasthole. Two blasters were killed and one injured in the three accidents.

High-explosive boosters ready to be lowered into a blasthole

Research and Development Activities

The Mine Safety and Health Administration asked explosives researchers at the Pittsburgh Research Laboratory (PRL) to assist in the investigation of these accidents. A borehole from the surface to the Bruceton Research Coal Mine was used to simulate a typical blasthole at a mine. Simulated boosters with detonators were dropped down the borehole to simulate two of the accidents. Impact geometry was varied to understand how the boosters may have detonated accidentally. Drop weight impact tests were conducted on the boosters and detonators to identify any unusual sensitivity to impact. Tests were conducted at Lake Lynn Laboratory to simulate what might happen if the detonator gets stuck in the booster and a blaster tries to pry it out with a knife. The findings showed that the accidents most likely occurred because the detonator well in the booster was partially plugged with foreign material such that a detonator could not be fully inserted, placing the detonator in a more exposed and hazardous position.

R&D Outputs and Transfer Activities

In 2000, PRL explosives researchers met with the manufacturer and the company's consultant. NIOSH researchers recommended that the booster be modified to incorporate a piece of tape over the detonator well to keep out foreign material.

Description of Intermediate Outcome

The manufacturer modified the specifications for its boosters according to NIOSH recommendations. Since the modification was made, there have been no further accidents involving this type of detonator and booster.

Outputs

3 Outputs

Title	Year	Output Type	Strategic Goal
MSHA Report, Summary of Explosive Testing Conducted Relative to the Accident at Material Service Quarry, Romeoville, IL Rowland-JH III; Mainiero-RJ	1999	Publication	Traumatic injuries
MSHA Report, Summary of Explosive Testing Conducted Relative to the Accident at Trapper Mining Inc., Craig CO Mainiero-RJ; Mytrysak-CA	1999	Publication	Traumatic injuries
MSHA Report, Summary of Testing Conducted Relative to Miller Quarry Accident Mainiero-RJ	1996	Publication	Traumatic injuries

Intermediate Outcome related to Reducing Traumatic Injuries and Fatalities in Blasting

Reduced NO_2 Production from Large-Scale Production Blasts at Surface Mines

Description of Problem

Over the past 10 years, large surface mines have been plagued by large orange or red product clouds produced by their large-scale blasting operations. The orange or red color of the cloud indicates high concentrations of nitrogen dioxide (NO_2), a highly toxic gas. There has been increasing concern over the effect of the NO_2 in the blasting product clouds on workers and neighbors.

Orange cloud produced by blasting at a surface coal mine

Research and Development Activities

On May 25, 2000, NIOSH researchers met with members of the Wyoming Mining Association (WMA) Red Smoke Committee to discuss how our research might help them to monitor and minimize the occurrence of blasting product clouds containing excessive concentrations of NO_2. The committee asked NIOSH for help in developing a plan to monitor NO_2 at its mines. A 3-year research project at the Pittsburgh Research Laboratory (PRL) was initiated to determine the causes for excessive NO_2 production in blasting. The research identified key factors that influenced the quantities of toxic fumes produced by various blasting agents.

R&D Outputs and Transfer Activities

PRL explosives researchers explained that they had used a variety of instrumentation to measure NO_2: a wet chemistry method, a chemiluminescence analyzer, a fixed electrochemical cell-based system, and portable electrochemical cell-based systems. NIOSH researchers also told WMA personnel that research had shown that excessive NO_2 production could be related to poor confinement, poor explosive formulation, and water contamination of the explosive. NIOSH recommended methods and strategies to reduce NO_2 production and minimize the potential for miner exposure.

Description of Intermediate Outcome

The gas monitoring protocol recommended by NIOSH researchers was incorporated into Thunder Basin Coal Co.'s action plan submitted to the Wyoming Department of Environmental Quality on April 7, 2000. It was also incorporated into the WMA's Powder River Basin Short-Term Exposure NO_2 Study. The mines in the Powder River Basin incorporated NIOSH research results into their blasting plans. These included lining blastholes and shooting with 100% emulsion blasting agent rather than ANFO/emulsion blends.

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
Chemical and Physical Factors that Influence N0x Production During Blasting: Exploratory Study Sapko-M; Rowland-J; Mainiero-R; Zlochower-I | In: Proceedings of the 28th Annual Conference on Explosives and Blasting Technique (Las Vegas, NV, Feb. 10-13, 2002). Vol. 2. Cleveland, OH: International Society of Explosives Engineers, 2002 Feb; :317-330	2002	Publication	Surveillance and training; Traumatic injuries
Factors Affecting ANFO Fumes Production Rowland-JH, III; Mainiero-RJ | In: Proceedings of the 26th Annual Conference on Explosives and Blasting Technique (Anaheim, CA, Feb. 13-16, 2000). Vol. 1. Cleveland, OH: International Society of Explosives Engineers, 2000 Feb; :163-174	2000	Publication	Traumatic injuries
Factors Affecting Fumes Production of an Emulsion and ANFO/Emulsion Blends Rowland-JH III; Mainiero-R; Hurd-DA Jr. | Proc 27th Ann Conf Explos Blasting Tech. Vol. II. Cleveland, OH: International Society of Explosives Engineers, 2001; :133-141	2001	Publication	Traumatic injuries
Wyoming Mining Association seminar Mainiero-RJ | Assisted Wyoming Mining Association in preparing seminar for industry experts and federal regulators, including the US EPA, on blasting techniques and nitrous oxide gases (Jan 2000)	2000	Workshop, Seminar, or OIB	Traumatic injuries

Strategic Program Outcome for Traumatic Injuries

Reducing Electrically Related Traumatic Injuries

Data from the Mine Safety and Health Administration (MSHA) show that from 1990 to 2004 fatal electrical accidents decreased by 50%, lost workday electrical accidents decreased by 75%, and lost workdays decreased by 60%. Nevertheless, electrical accidents remained the fourth leading cause of on-the-job death in mining. The goal of the NIOSH electrical safety research program is to forge innovative solutions to existing and emerging problems in mine electrical safety. Research has focused on a variety of topics, including trailing cables, motors, trolley systems, ground fault protection, intrinsic safety, explosion-proof enclosures, overhead power lines, and lasers. For example, several aspects of electrical safety research have contributed to new and proposed changes in mining safety law that will dramatically increase high-voltage electrical safety and expedite new technology into the marketplace. Other electrical safety research is leading toward new safety standards for equipment that operates near high-voltage power lines.

Demand for larger, more powerful mining equipment stimulated the need for increased voltages for coal mine face machinery. Several NIOSH studies showed that higher voltages were feasible. The resultant research reports provided technical information to MSHA that was used to help formulate new regulations. These regulations went into effect on May 10, 2002, and allowed the use of high-voltage longwall machines in coal mines. The reports also contributed to the formulation of proposed new regulations for high-voltage continuous miners. These are now in the formal rulemaking process.

MSHA data show that nearly one-fifth of mine electrical deaths occur when workers contact overhead power lines. Research to protect workers from overhead power line electrocution led to one patent and stimulated two U.S. manufacturers to introduce stand-alone power line contact alarms.

Laser technology has become common in several fields, e.g., surveying and level detection. The use of lasers in potentially hazardous underground atmospheres was recognized as a new area of concern. Research was done to measure the risk of igniting flammable atmospheres by radiation from optical equipment. American National Standards Institute and International Electrotechnical Commission standards are now in process, based in part on NIOSH laser ignition research. These standards will result in safety guidelines for the safe use of lasers in gassy and dusty atmospheres.

These and other contributions of the NIOSH electrical safety research program have led to improved electrical safety for the U.S. mining workforce.

Intermediate Outcomes

- Contact Warning Alarm System to Reduce Overhead Power Line Injuries
- Electrical Safety Training to Reduce Overhead Power Line Injuries
- MSHA High-voltage Longwall Regulations
- Proposed MSHA Regulation to Improve High-voltage Continuous Miner Electrical Safety
- Research Guidelines Based on an Analysis of Occupational Electrical Injuries
- Using Lasers in Potentially Flammable Environments: Recommendations on Safer Limits

Intermediate Outcome related to Reducing Electrically Related Traumatic Injuries

Contact Warning Alarm System to Reduce Overhead Power Line Injuries

Description of Problem

High-voltage power line contact by a crane hoist cable

During the 1990s, about 20% of all mining electrocutions resulted from high-reaching mobile equipment that made contact with overhead electric power lines. A detailed analysis of these accidents revealed that 56% of the injured miners had contacted the equipment and ground simultaneously after the power line contact had occurred and were unaware of the shock hazard. These workers could have avoided injury had they simply known after the fact that the equipment had become energized. An overhead power line contact alarm, while not designed to avoid all related injuries, is a reliable, affordable, and practical alternative to proximity warning systems. Contact alarm technology could also reduce power line-related electrical injuries in other industries, such as construction. This system was developed to warn workers when a piece of mobile equipment becomes energized by a power line.

Research and Development Activities

NIOSH research identified one important aspect of power line electrocution little mentioned in the literature: workers are often killed or injured by electrically energized equipment before they are even aware of the hazard. NIOSH hypothesized that a system to alert operators and nearby ground crew workers could prevent more than half of these injuries in mining. Baseline experiments characterized voltage rises and danger areas on energized cranes and dump-bed trucks for equipment operators and other workers. Follow-on research identified two methods of power line contact detection. Undercarriage electric fields were identified as the most reliable detection method because of their ability to detect power line contact on all common road surfaces. Prototype technology was designed, built, tested, and transferred to industry.

R&D Outputs and Transfer Activities

The results of overhead power line hazard and contact alarm research and recommended hazard mitigations were published in several technical articles. An invited 90-minute workshop on Electrical Safety for Water Well Drillers was held at the National Ground Water Association annual meeting in Las Vegas, NV, December 12, 2004, and twice at the South Atlantic Water Well Driller's Jubilee, Myrtle Beach, SC, July 30-31, 2005. A U.S. patent for the "Alarm System for Detecting Hazards Due to Power Transmission Lines" was awarded on July 29, 2003.

Description of Intermediate Outcome

In 2004, the largest manufacturer of power line proximity warning alarms, Allied Safety Systems, Inc. (Sanford, FL), added undercarriage electric field detection as an option to its existing product line of power line proximity warning devices. This resulted, in part, from discussions with NIOSH engineers regarding the contact alarm concept. Allied plans to add a low-cost, stand-alone undercarriage power line contact alarm to its product line. Another manufacturer, Hirschmann Electronics, Inc./PAT America plans to introduce a power line proximity warning alarm that includes an undercarriage power line contact alarm as both an add-on and a low-cost, stand-alone product. With the market for proximity warning alarms systems estimated at 45,000 worldwide, the potential to reduce power line contact accidents is high.

Outputs

6 Outputs

Title	Year	Output Type	Strategic Goal
Alarm System for Detecting Hazards Due to Power Transmission Lines Sacks-HK; Yenchek-MR; Homce-GT; Cawley-JC | U.S Patent #6,600,426 (granted July 29, 2003)	2003	Patent	Traumatic injuries
Development of an Overhead Power Line Contact Alarm for Mobile Equipment Homce-GT; Cawley-JC; Sacks-HK; Yenchek-MR | International Journal of Heavy Vehicle Systems, (12)4, 2005 Apr; :87-103	2005	Publication	Traumatic injuries
Feasibility Study to Reduce Injuries and Fatalities Caused by Contact of Cranes, Drill Rigs, and Haul Trucks with High-Tension Lines Sacks-HK; Cawley-JC; Homce-GTR; Yenchek-MR | IEEE Trans Ind Appl, 37(3), 2001; :914-919	2001	Publication	Traumatic injuries
Heavy Equipment Near Overhead Power Lines? New Safety Research May Save Your Life: New Safety Research May Save Your Life Homce-GT; Cawley-JC; Sacks-HK; Yenchek-MR | Engineering and Mining Journal, (203)4, 2002 Apr :36-39	2002	Publication	Traumatic injuries
Electrical Safety for Water Well Drillers An invited, 90-minute workshop held at the National Ground Water Association annual meeting in Las Vegas, NV, December 12, 2004	2004	Workshop, Seminar, or OIB	Traumatic injuries
Electrical Safety for Water Well Drillers NIOSH | An invited, 90-minute workshop held twice at the South Atlantic Water Well Driller's Jubilee, Myrtle Beach, SC, July 30-31, 2005	2005	Workshop, Seminar, or OIB	Traumatic injuries

Intermediate Outcome related to Reducing Electrically Related Traumatic Injuries

Electrical Safety Training to Reduce Overhead Power Line Injuries

Description of Problem

The wide dissemination of electrical safety information depends on the actions of many groups. Based on its analysis of electrical safety in general industry, NIOSH was invited to participate on the Workplace Safety Committee of the Electrical Safety Foundation International (EFSI). ESFI is North America's only nonprofit organization dedicated exclusively to promoting electrical safety in the home, school, and workplace. NIOSH is now an active participant in this valuable collaboration to promote electrical safety.

Crane boom involved in an overhead power line contact fatal accident

Research and Development Activities

In 2004, the ESFI's Workplace Safety Committee produced the pamphlet "Look Up, Look Down, Look Out!" This was a joint educational effort between ESFI and its partners, including NIOSH, the Occupational Safety and Health Administration (OSHA), the National Safety Council, du Pont, Siemens, General Electric, Leviton, Square D, and other large electrical manufacturers and suppliers in the United States. The pamphlet raises awareness of the hazard of overhead power lines. A testimonial by Olympic gold medalist Cliff Meidl, who was injured in a power line accident, leads off the pamphlet. This is followed by a self-administered quiz to both attract the user's attention and to convey power line safety facts. All quiz responses contain true information regarding power line hazards. The reader is then referred to websites of CDC, OSHA, the National Fire Protection Association, and the Construction Safety Council for more information.

R&D Outputs and Transfer Activities

NIOSH played a major role in orienting the ESFI Workplace Safety Committee's educational effort. NIOSH also contributed significantly to the conceptual development of the pamphlet. Another educational pamphlet to emphasize electric shock prevention in the workplace is in process.

Description of Intermediate Outcome

During the 1990s, accidental contact with overhead power lines was implicated in 20% of mine electrical deaths and nearly half of all other on-the-job electrical deaths. The power line injury hazard is quite similar in mining, construction, manufacturing, and other industries. Electrical safety improvements in one industry can easily cross over into others. Small contractors and Latino workers are two high-risk target groups for power line accidents. These groups require innovative avenues for dissemination of information. The ESFI pamphlet carries the overhead power line hazard awareness message to small contractors via distribution at the contractor's sales desks of Home Depot and Lowe's stores, as well as equipment rental companies. Reaching the small

contractor audience in both English and Spanish will increase hazard awareness, a first step in accident reduction. The pamphlet is available in English and will soon be available in Spanish. About 800 copies have been sold. We expect future interactions between NIOSH and the ESFI to continue to raise workplace electrical hazard awareness in this and other areas.

Outputs

1 Output

Title	Year	Output Type	Strategic Goal
Look Up, Look Down, Look Out ESFI, OSHA, and NIOSH | Rosslyn, VA: Electrical Safety Foundation International, Inc.; :2 pp	2004	Publication	Traumatic injuries

Intermediate Outcome related to Reducing Electrically Related Traumatic Injuries

MSHA High-voltage Longwall Regulations

Description of Problem

High-voltage longwall equipment

The demand for larger, more powerful mining equipment stimulated the need for increased voltages for coal mine face machinery. Higher-voltage equipment can supply more power without the need for larger, heavier portable cables. Special design, use, and maintenance precautions are needed to ensure an equivalent level of safety when high-voltage systems are used in permissible areas. Prior to passage of the Mine Safety and Health Administration's (MSHA) final rule for high-voltage longwall machines, the voltage limit for type-accepted permissible longwall machines was 1,000 V ac. Equipment operating above 1,000 V ac required a petition for modification. This entailed an approval examination for each high-voltage longwall machine deployed inby, which greatly slowed the industry penetration of this more productive mining equipment.

Research and Development Activities

NIOSH research showed that higher voltages for face equipment was feasible with appropriate precautions. Under one study, a 750-kVA explosion-proof load center was built that was used by MSHA's Approval and Certification Center as a test bed. It provided important information about large-scale, high-voltage, explosion-proof equipment. Another research study produced finite-element stress calculations and a material analysis, the results of which helped formulate the final rule.

R&D Outputs and Transfer Activities

Several NIOSH reports provided technical information to MSHA that was used to help formulate new regulations to allow the use of high-voltage longwall machines in coal mines. The information included the enclosure pressures developed during electrical arcing at up to 15 kV in methane-air atmospheres. Also included were recommendations for high-voltage electrical creepage and clearance distances, design criteria for explosion-proof enclosures, and permissibility hazard reduction. The final rule credits two separate NIOSH research reports that were used to help formulate its technical language.

Description of Intermediate Outcome

MSHA published its final rule for 30 CFR 18 and 75, "Electric Motor-Driven Mine Equipment and Accessories and High-Voltage Longwall Equipment Standards for Underground Coal Mines" on March 11, 2002 (Federal Register, Vol. 67, No. 47, March 11, 2002, Rules and Regulations, pp. 10972-11005): http://www.dol.gov/msha/regs/fedreg/final/2002004863.pdf. This final rule established MSHA's new mandatory electrical safety standards for the installation, use, and maintenance of high-voltage longwall mining systems used in underground coal mines. The final rule also included design approval requirements for high-voltage equipment operated in longwall face areas of underground mines. The new provisions allow the use of high-voltage longwall face equipment with enhanced protection from fire, explosion, and shock hazards without the need for a petition for modification. This regulation ensures an equivalent level of electrical safety and streamlines the approvals process.

Outputs

8 Outputs

Title	Year	Output Type	Strategic Goal
A Design Guide for Explosion-Proof Electrical Enclosures Cox-PA; Scott-LW | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 8893. NTIS No. PB 83-119487	1982	Publication	Traumatic injuries
A Study of Explosion-Proof Enclosures Cox-PA; Burnside-OH; Esparza-ED; Lin-FD; White-RE | San Antonio, TX: Southwest Research Institute. USBM contract No. H0-377052. OFR 96-83, NTIS No. PB 83-205450; :426 pp	1982	Publication	Traumatic injuries
Development of High-Voltage Permissible Loadcenter Berry-DR; Gillenwater-B | U.S. Bureau of Mines contract no. H0308093. NTIS No. PB 86-215803	1986	Publication	Traumatic injuries
Development of Recommended Criteria and Test Facilities for Acceptance of High-Voltage Permissible Loadcenters and Switchgear Enclosures Massey-AB | U.S. Department of Labor, Mine Safety and Health Administration. U.S. Bureau of Mines contract No. J0333909. NTIS No. PB 87-157434	1986	Publication	Traumatic injuries
Mine Electrical Systems Evaluation: Explosion-Proofing of Mine Containers Stefanko-R; Morley-LA | University Park, PA: The Pennsylvania State University, College of Earth and Mineral Sciences. U.S. Bureau of Mines Contract Report No. G0-133077, OFR 76(2)-75, NTIS Number: PB/245-928/As, 76 pp	1974	Publication	Traumatic injuries
Mine Power Systems Morely-LA | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9258. NTIS No. PB 91-241729	1990	Publication	Traumatic injuries
The Effects of Cable Capacitance on Longwall Power Systems Novak-T; Basar-J; Sottile-J; Kohler-JL | IEEE Trans Ind Appl 40(5), 2004; :1406-1412	2004	Publication	Traumatic injuries
Electric Motor-Driven Mine Equipment and Accessories and High-Voltage Longwall Equipment Standards for Underground Coal Mines Federal Register, Vol. 67, No. 47, March 11, 2002, Rules and Regulations, pp. 10972-11005	2002	Standards	Traumatic injuries

Intermediate Outcome related to Reducing Electrically Related Traumatic Injuries

Proposed MSHA Regulation to Improve High-voltage Continuous Miner Electrical Safety

Description of Problem

High-voltage continuous miner

The demand for larger, more powerful mining equipment stimulated the need for increased voltages for coal mine face machinery. Higher-voltage equipment can supply more power without the need for larger, heavier trailing cables. Special design, use, and maintenance precautions are needed to ensure an equivalent level of safety when high-voltage systems are used in permissible areas. The voltage limit for type-accepted continuous miners is 1,000 V ac. Equipment operating above 1,000 V ac requires a petition for modification. This entails an approval examination for each high-voltage continuous miner deployed inby.

Research and Development Activities

NIOSH conducted research studies indicating that higher voltages for face equipment was feasible with appropriate precautions. In addition to the studies used to develop the high-voltage longwall final rule, Information Circular (IC) 9258, "Mine Power Systems," provided information used to specify important shock protection sections of the continuous miner proposed rule.

R&D Outputs and Transfer Activities

Results drawn from at least five separate NIOSH reports were used to help formulate the technical language in the proposed rule. These studies provided critical parts of the technical basis for the proposed MSHA regulations. The information used from the reports included the enclosure pressures developed during electrical arcing at up to 15 kV in methane-air atmospheres. Also included were recommendations for high-voltage electrical creepage and clearance distances, design criteria for explosion-proof enclosures, permissibility hazard reduction, and ground fault protection. MSHA used these reports in rulemaking regarding Part 6 equivalency determinations for Part 18 enclosures. MSHA also used them to help reconcile philosophical differences in other standards (both foreign and domestic) for designing explosion-proof enclosures.

Description of Intermediate Outcome

MSHA has proposed new requirements (Federal Register, July 16, 2004, Vol. 69, No. 136, proposed rules, pp. 42811-42840) for the approval of high-voltage continuous mining machines operating in face areas of underground mines: http://www.msha.gov/REGS/FEDREG/PROPOSED/2004prop/04-15841.pdf. The proposed rule was published to allow type acceptance of continuous mining machines, thus avoiding the petition for modification process for each high-voltage continuous miner placed into service. MSHA also

proposed new mandatory electrical safety standards for the installation, use, and maintenance of high-voltage continuous mining machines used in underground coal mines. These provisions will enable mines to use type-accepted high-voltage continuous mining machines with enhanced safety protection from fire, explosion, and shock hazards.

Outputs

7 Outputs

Title	Year	Output Type	Strategic Goal
A Design Guide for Explosion-Proof Electrical Enclosures Cox-PA; Scott-LW | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 8893. NTIS No. PB 83-119487	1982	Publication	Traumatic injuries
A Study of Explosion-Proof Enclosures Cox-PA; Burnside-OH; Esparza-ED; Lin-FD; White-RE | San Antonio, TX: Southwest Research Institute. USBM contract No. H0-377052. OFR 96-83, NTIS No. PB 83-205450; :426 pp	1982	Publication	Traumatic injuries
Development of High-Voltage Permissible Loadcenter Berry-DR; Gillenwater-B | U.S. Bureau of Mines contract no. H0308093. NTIS No. PB 86-215803	1986	Publication	Traumatic injuries
Development of Recommended Criteria and Test Facilities for Acceptance of High-Voltage Permissible Loadcenters and Switchgear Enclosures Massey-AB | U.S. Department of Labor, Mine Safety and Health Administration. U.S. Bureau of Mines contract No. J0333909. NTIS No. PB 87-157434	1986	Publication	Traumatic injuries
Mine Electrical Systems Evaluation: Explosion-Proofing of Mine Containers Stefanko-R; Morley-LA | University Park, PA: The Pennsylvania State University, College of Earth and Mineral Sciences. U.S. Bureau of Mines Contract Report No. G0-133077, OFR 76(2)-75, NTIS Number: PB/245-928/As, 76 pp	1974	Publication	Traumatic injuries
Mine Power Systems Morely-LA | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9258. NTIS No. PB 91-241729	1990	Publication	Traumatic injuries
High-Voltage Continuous Mining Machines RIN 1219-AB34, Federal Register, July 16, 2004, Vol. 69, No. 136, proposed rules, pp. 42811-42840	2004	Standards	Traumatic injuries

Intermediate Outcome related to Reducing Electrically Related Traumatic Injuries

Research Guidelines Based on an Analysis of Occupational Electrical Injuries

Description of Problem

Arc resistant personal protective clothing

A comprehensive look at electrical injury in mining and other industries was needed to help refocus the electrical safety research. Injury from electric arcs forms the largest single category of nonfatal electrical injuries in mining. A significant industrial electrical safety research effort has focused on protecting workers from electrical arcing hazards. National Fire Protection Association (NFPA) standard 70E, "Standard for Electrical Safety Requirements for Employee Workplaces," explicitly excludes underground mining from its scope. In addition, accidental contact with overhead power lines was implicated in 20% of mine electrical deaths and nearly half of all other on-the-job electrical deaths. Many of these power line accidents were thought to be preventable.

Research and Development Activities

Two analyses were completed. One focused specifically on mining electrical injury and helped refocus mine electrical safety research toward electrical arcing fault injury. The second analysis of electrical injury patterns showed that power line accidents are the single greatest on-the-job fatal electrical hazard in general industry. Recommendations to fill research gaps were made.

R&D Outputs and Transfer Activities

The NIOSH research products gained wide acceptance in the electrical safety community. Results were given at an invited presentation at the IEEE IAS PCIC Electrical Safety Workshop, Oakland, CA, in 2003 and were published in several technical articles that analyzed injuries in the electrical industry.

Description of Intermediate Outcome

Refocused NIOSH mine electrical research is now bringing the relevant aspects of NFPA 70E into the mining workplace to afford miners better protection from electrical arcing injury. NIOSH attacked the power line injury problem by attempting to influence stakeholder groups to devote more of their research efforts to this area. Influential contacts in the electrical safety community now recognize the magnitude of the power line problem and are more receptive to research and cooperation in this area. In addition, training efforts have made inroads into other industries such as water well drilling, where power line contact is the leading killer. The electrical industry injury analysis published by NIOSH was described by IEEE Industry Applications Applications Society

(IAS) President-elect H. Landis Floyd II as a "landmark study" of electrical injury in his column in the March-April 2004 issue of IEEE *Industry Applications Magazine*, and it was cited again in the May-June 2004 issue. This analysis has begun to shift research focus among IEEE Petroleum and Chemical Industry Committee (PCIC) electrical safety professionals toward the overhead power line problem. The analysis was also cited in several other technical journals.

Outputs

2 Outputs

Title	Year	Output Type	Strategic Goal
Electrical Accidents in the Mining Industry, 1990-1999 Cawley-JC | IEEE Trans Ind Appl 2003 Nov/Dec, 39(6;):1570-1577	2003	Publication	Traumatic injuries
Occupational Electrical Injuries in the United States, 1992-1998, and Recommendations for Safety Research Cawley-JC; Homce-GT | J Safety Research 2003 Aug; 34(3):241-248	2003	Publication	Traumatic injuries

Intermediate Outcome related to Reducing Electrically Related Traumatic Injuries

Using Lasers in Potentially Flammable Environments: Recommendations on Safer Limits

Description of Problem

The use of laser and other optical beam equipment in gassy and dusty atmospheres was generally thought to be safe. For example, laser-based level monitors are used in coal storage facilities. Laser-guiding fiber-optic cables for telecommunications have been installed inside natural gas pipelines in several states. Guidelines were needed to define if and when a laser beam can be considered a potential ignition source in such environments.

Installation of a fiber optic communications cable in a natural gas line

Research and Development Activities

Research to determine the risk of laser-based optical equipment igniting a flammable atmosphere was done to support the development of national and international laser safety standards. Continuous-wave, diode-array lasers and fiber lasers were used to measure the dimensions and durations of the laser beams needed to ignite flammable gas atmospheres and dust clouds. Atmospheres containing methane, propane, and butane were tested. Iron oxide was deposited on the end of a fiber to simulate a broken fiber in a dirty environment. Lean mixtures of methane ignited at 410 mW, rich mixtures of butane at 300 mW, and rich mixtures of propane at 250 mW. Two types of coal dust clouds were also tested. The significant findings were that Pittsburgh seam coal and Powder River Basin coal both ignited using 2 W out of a beam diameter of 0.2 mm. Corn starch, an easily ignitable grain dust, was also tested and found to ignite using 1.5 W out of a 0.2-mm-diam fiber.

R&D Outputs and Transfer Activities

NIOSH research helped form the basis of the American National Standards Institute (ANSI) and International Electrotechnical Commission (IEC) documents on laser safety in flammable atmospheres. Research results were published in two technical articles. A U.S. patent , "Method and Apparatus for Safety Testing Optical Systems for Hazardous Locations," was awarded on December 23, 2003.

Description of Intermediate Outcome

ANSI cited NIOSH research results in its technical report (ANSI/ISA-TR12.21.01-2004) on fiber optics used in flammable environments. The report also credits NIOSH as the lead developer of the document. It was used as the base document for an IEC standard, which is in the "committee draft for vote" stage. The draft document, IEC 60079-28 Ed. 1.0: "Protection of Equipment and Transmission Systems Using Optical Radiation," also cites NIOSH research. In addition, the Mine Safety and Health Administration published a notice of intent to review parts of the IEC 60079 standard for application to U.S. mining equipment approvals. Safety recommendations called out by the ANSI technical report are cited in a draft American Society for Testing and Materials International Standard WK2307, "Standard Specification for Selection of Fiber-optic Cable and System Components for Use in Natural Gas Pipelines." Collectively, these standards help ensure that laser applications can be installed safely in mines and other flammable environments.

Outputs

5 Outputs

Title	Year	Output Type	Strategic Goal
Continuous Wave Laser Ignition Thresholds of Coal Dust Clouds Dubaniewicz-TH Jr; Cashdollar-KL; Green-GM | Journal of Laser Applications, 2003 Aug; 15(3):184-191	2003	Publication	Mine disasters; Traumatic injuries
Ignition of Methane-Air Mixtures by Laser Heated Small Particles Dubaniewicz-TH Jr; Cashdollar-KL; Green-GM; Chaiken-RF | Journal of Loss Prevention in the Process Ind, 2000 May 13(3-5):349-359	2000	Publication	Traumatic injuries
Method and Apparatus for Safety Testing Optical Systems for Hazardous Locations Dubaniewicz-TH; Green-GM | U.S Patent #6,667,801 (granted December 23, 2003)	2003	Patent	Traumatic injuries
Draft ASTM International Standard - WK2307, Standard Specification for Selection of Fiber-Optic Cable and System Components for Use in Natural Gas Pipelines ASTM | Technical report ANSI/ISA-TR12.21.01-2004	2004	Standards	Traumatic injuries
Final Draft International Standard IEC 60079-28 Ed. 1.0: Protection of Equipment and Transmission Systems Using Optical Radiation IEC	2005	Standards	Traumatic injuries

Strategic Program Outcome for Traumatic Injuries

Reducing Machine-related Traumatic Injuries

Despite advances in mechanization, mining remains among the most physically demanding and hazardous of all occupations. Traumatic injuries resulting from machinery, powered haulage, and falls have long been identified as a significant problem for the mining industry. According to the Mine Safety and Health Administration (MSHA), during 1995-2004 there was a 42% decrease in days lost due to machinery injuries, a 51% decrease in days lost due to powered haulage injuries, and a 34% decrease in days lost due to falls.

NIOSH contributed to this significant improvement through its machine safety research program. NIOSH-developed research products and recognized experise are being used by our stakeholders to further reduce the risk of machine-related injuries. Examples include:

- *A close-proximity warning device:* The research product (HASARD - Hazardous Area Signaling and Ranging Device) has been recently licensed to three firms that manufacture the system for their own use and commercial sales.
- *Technical guidance in the application of proximity warning systems:* MSHA and equipment manufacturers make use of NIOSH expertise to aid in decision-making on effective proximity warning systems and technologies to prevent accidents.
- *A set of best practices for system safety:* NIOSH collaborative research has developed a set of documents relating to the safety life cycle for programmable electronic mining systems. The research has been integrated into the national and international mining communities.
- *A computer program that evaluates mine illumination systems:* NIOSH-developed software (called the Crewstation Analysis Program) is routinely used by MSHA´s Approval and Certification Center in the approval process for mine lighting systems.

Miners interact with a wide assortment of machinery and tools in the course of their work. They work in an environment that is dynamic and often unforgiving. Work environments involving extraction, bolting, and haulage require the integration of large mobile machinery working in confined space. It is a recipe for danger as the consequence of small errors can be serious. According to MSHA, 10 miners on average are killed each year by being run over or pinned by mobile mining equipment. Therefore, a systematic study of the interaction of miners, their tools and equipment, and their work environment is needed to reduce the risk of serious injury.

Both labor and industry have expressed the need for a "systems perspective" to reduce the risk of serious injury. A systems perspective requires the integration of human-centered design principles with new mining technology. Little research has been done in this area partially because of the difficulty and potential dangers in collecting sufficient data in the underground and surface work environments. However, with advances in computer modeling and simulation methods, coupled with the unique test facilities of the NIOSH Mining Program, most of the data can be collected either virtually or in simulated environments. This allows for the integration of human-centered design principles into work system and machinery design.

The basis for current and future work is risk assessment. Proactively researching issues that can integrate a large number of system variables (e.g., visibility, work station and control design, computerized control of machinery, and maintenance and repair tasks) will promote the better design of new technology to reduce risk. Partnering with the United Mine Workers of America, original equipment manufacturers (e.g., Joy Mining Machinery, Inc., J. H. Fletcher & Co., DBT America), and government agencies (MSHA) will proactively develop and disseminate science-based solutions to the mining industry.

Reducing accidents associated with machinery, powered haulage, and falls in mining requires full-scale testing and analysis of equipment and apparatus. Without a regulatory impetus, manufacturers are often unwilling to invest in finding solutions to these safety hazards. The NIOSH Mining Program is unique in its test facilities for full-scale evaluation of mining machinery. Our record of partnering with industry and labor will help to proactively develop and disseminate injury prevention strategies.

Intermediate Outcomes

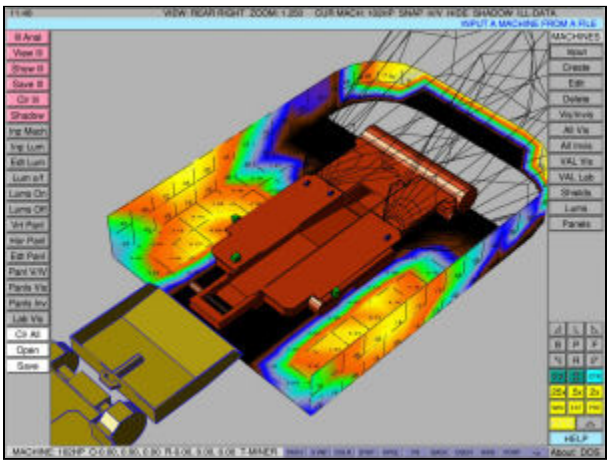
- Crewstation Analysis Programs (CAP) to Reduce Injuries Due to Sub-Optimal Machine Illumination Systems
- Guidance for Applying Proximity Warning Systems to Surface Mine Equipment
- Proximity Warning System for Reducing Injuries Pertaining to Mobile Mining Equipment
- System Safety Best Practices to Reduce Injuries due to Malfunctioning Computerized Mining Systems

Intermediate Outcome related to Reducing Machine-related Traumatic Injuries

Crewstation Analysis Programs (CAP) to Reduce Injuries Due to Sub-Optimal Machine Illumination Systems

Description of Problem

Restricted fields of vision are a common problem with underground mining equipment, particularly in lower seams. In addition, when lighting systems are provided underground, they are often positioned where they cause excessive glare. This limits visibility around the machines even further. Evaluations of mining lighting systems are required by 30 CFR 75.1719. Typical ways to do this are to take actual light readings on machines underground or on mockups in an accepted darkroom.



Screenshot of CAP evaluating an illumination system

Research and Development Activities

NIOSH collaborative research has led to improved practices for assessing alternative illumination designs for underground mining systems. Researchers developed an improved software package (Crewstation Analysis Programs (CAP)) to assess and evaluate machine-mounted illumination systems.

R&D Outputs and Transfer Activities

The Mine Safety and Health Administration's Approval and Certification Center routinely uses the CAP software in the approval process for mine lighting systems. Use of the software results in significant cost and time savings to mining machine manufacturers and MSHA for a critical aspect of machine design.

CAP software is used by all major U.S. mine lighting manufacturers (Ocenco, Inc., and Mining Controls, Inc.). MSHA uses CAP in its Statement of Test and Evaluation (STE) procedures because it is more accurate and less costly than traditional methods for assessing illumination levels. NIOSH continues to collaborate with MSHA to provide enhancements to the CAP software.

Although there are no illumination standards for surface mining, the CAP software has been used to design lighting systems for surface equipment. CAP has also been requested by several foreign countries, but NIOSH has not yet received any feedback on its use.

Description of Intermediate Outcome

- MSHA Criteria for Using the Crewstation Analysis Programs to Acquire Light Survey Data Required for STE Applications: http://www.msha.gov/techsupp/acc/application/acri2006.pdf

- MSHA has published requirements referencing the CAP software in its Standard Application Procedure for Statement of Test and Evaluation (STE) for Mining Machines and Longwall Mining Systems: http://www.msha.gov/techsupp/acc/application/asap2023.pdf
- MSHA has published criteria referencing CAP for Acquiring Illumination Data in an STE Applicant's Darkroom: http://www.msha.gov/techsupp/acc/application/acri2002.pdf
- MSHA has published a Standard Test Procedure to Collect ISO-Footcandle Illumination Curves at Independent Light Laboratories: http://www.msha.gov/techsupp/acc/standardtestprocs/astp2050.pdf

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
An Easy to Use PC Based Lighting and Visibility Analysis Software Package for Underground Mining Equipment Unger-RL | Bureau of Mines Special Publication SP 18-94, 1994; :133-139	1994	Publication	Traumatic injuries
Computer Design and Evaluation Tool for Illuminating Underground Coal-Mining Equipment Gallagher-S; Mayton-AG; Unger-RL; Hamrick-CA; Sonier-P | Journal of the Illuminating Engineering Society 25(1), 1996; :3-12	1996	Publication	Traumatic injuries
Crewstation Analysis Programs Reference Manual: Procedures to Collect Photometric Data for the Computer Modeling of Underground Machine Mounted Lighting Systems - First Edition Unger-RL; Mayton-AG; Rossi-EW | Bureau of Mines Special Publication 23-94	1994	Publication	Traumatic injuries
Crewstation Analysis Programs (CAP) Unger-RL | NIOSH 1996; :Software	1996	Software	Traumatic injuries

Intermediate Outcome related to Reducing Machine-related Traumatic Injuries

Guidance for Applying Proximity Warning Systems to Surface Mine Equipment

Description of Problem

An accident due to lack of visibility

An average of 40 accidents and five fatalities occur each year in the U.S. surface mining industry that can be attributed to the lack of visibility around large, off-highway mining equipment. These accidents account for 12% of all surface mine fatalities. They fall into two main categories: (1) collisions between mining equipment and smaller vehicles, workers on foot, structures, or other equipment and (2) driving or backing over the edge of an embankment, stock pile, dump point, or other change in terrain. The areas surrounding the equipment that an operator cannot see from the cab can be extensive and are a major contributing factor.

Research and Development Activities

In 1998, the Mine Safety and Health Administration (MSHA) proposed rules requiring some type of sensor-based proximity warning system and cameras to monitor blind areas around mining equipment. At that time, no sensor-based technology had been thoroughly tested on large, off-highway mining equipment. Cameras had been applied only to a limited extent. NIOSH proposed that a test program be initiated for off-the-shelf proximity warning systems to see how they performed on mining equipment before finalizing any rules. For the past few years, NIOSH and MSHA have been working together to evaluate proximity warning systems in order to understand their applications and limitations on mining equipment.

NIOSH developed a test protocol to evaluate various warning systems and studied available technology to assess which systems are most effective in preventing collisions in surface mining conditions. A combination of an off-the-shelf radar system and a camera has been thoroughly tested at a surface mine. Tests have also been done on innovative systems developed in cooperation with outside organizations. These include a GPS-based system and a stereovision system.

R&D Outputs and Transfer Activities

During 2001-2005, the results of this research were transferred to the mining industry through 13 technical publications and nine presentations. This research also assisted MSHA in publishing a Web page with information and training material on proximity warning systems.

Description of Intermediate Outcome

The NIOSH-originated procedures for testing and integrating protocols for use of proximity warning systems are being used by the mining industry, MSHA, and equipment manufacturers to make decisions about the most effective technologies to prevent accidents. NIOSH has provided input to MSHA regarding new regulations to improve the safety of operating surface mine haulage equipment. Some of the outcomes are as follows:

- NIOSH researchers were asked to act as subject matter experts and committee members during the development of the International Standards Organization (ISO) standard 16001 - Earth moving machinery - Hazard detection systems and visual aids - Performance requirements and tests. NIOSH Reports of Investigations (Ris) were referenced in the standard. Also, a NIOSH researcher wrote sections of the standard dealing with test procedures for radar (annex C) and tag-based proximity warning systems (annex F). This ISO standard can be accessed at: http://www.iso.org/
- The Canadian CIM Bulletin (Vol. 93, No. 1045) cited a NIOSH study that is evaluating proximity warning systems to monitor blind areas near mining equipment. The article is entitled "New Technology Makes Safety Easier."
- The United Kingdom's Health and Safety Executive (HSE) cited NIOSH test results on proximity warning systems in its report entitled "Improving the Safety of Workers in the Vicinity of Mobile Plant" (contract research report 358/2001). The NIOSH work was referred to as "arguably the most comprehensive comparative testing of vehicle and personnel detection systems."
- MSHA used NIOSH study results to publish a Web page describing available proximity warning systems for mining equipment. It is entitled "Accident Prevention through the use of New Technologies" and is available at http://www.msha.gov/.
- Caterpillar, Inc. and Phelps Dodge, Inc. are using NIOSH study results to make decisions about implementing proximity warning systems on mining equipment. A NIOSH researcher has been asked by Caterpillar to act as a subject matter expert on a work group that is designing a system for mining and construction equipment. Phelps Dodge has participated in NIOSH tests and is using NIOSH study results to select systems for large-scale tests.
- NIOSH worked closely with Preco Electronics, Boise, ID, to modify its existing radar-based proximity warning system so that it would work more effectively on large, off-highway equipment. NIOSH recommendations were incorporated in a radar system that uses multiple antennas to provide a wider obstacle detection area while monitoring both the front and rear of the equipment.

Outputs

17 Outputs

Title	Year	Output Type	Strategic Goal
Application of Radar To Detect Pedestrian Workers Near Mining Equipment Ruff-TM | Applied Occupational and Environmental Hygiene, 16(8), 2001; :798-808	2001	Publication	Traumatic injuries
Application of Radio-Frequency Identification Systems to Collision Avoidance in Metal/Nonmetal Mines Ruff-TM; Hession-Kunz-D | IEEE Transactions on Industry Applications, 37(1), 2001; :112-116	2001	Publication	Traumatic injuries
Evaluation of Devices to Prevent Construction Equipment Backing Incidents Ruff-TM | SAE Commercial Vehicle Engineering Congress and Exhibition (Oct. 26-28, 2004; Chicago, IL). Paper 2004-01-2725; :10 pp	2004	Publication	Traumatic injuries
Evaluation of Systems to Monitor Blind Areas Behind Trucks Used in Road Construction and Maintenance: Phase 1 Ruff-TM | NIOSH Report of Investigations 9660, 2003 Feb; :1-15	2003	Publication	Traumatic injuries
Mine Eyes: Proximity Alert for Monster Trucks Ruff-TM; Holden-TP | GPS World, 2002 Jul; :16-22	2002	Publication	Traumatic injuries
Miner Training Simulator: Users Guide and Scripting Language Documentation Ruff-TM | NIOSH Information Circular 9457, 2001 Jun; :1-21	2001	Publication	Surveillance and training; Traumatic injuries
Monitoring Blind Spots: A Major Concern for Haul Trucks Ruff-TM | Engineering and Mining Journal, 202(12), 2001 Dec; :17-26	2001	Publication	Traumatic injuries
New Technology To Monitor Blind Areas Near Surface Mining Equipment Ruff-T | Crossroads to Innovation, Conference Record of the 2003 Institute of Electrical and Electronics Engineers and 38th Annual Meeting of Industry Applications Society (Oct 12-16, 2003; Salt Lake City, UT), Available from the author and on CD-ROM from IEEE, Piscataway, NJ, 2003 Oct; :7 pp	2003	Publication	Traumatic injuries
Preventing Collisions Involving Surface Mining Equipment: A GPS-Based Approach Ruff, Todd M., and Thomas P. Holden | Journal of Safety Research, vol. 34, 2003; :175-181	2003	Publication	Traumatic injuries
Recent Advances in Proximity Warning Technology for Surface Mining Equipment Ruff-TM; Steele-J | Mining Engineering, 56(12); :68-72	2004	Publication	Traumatic injuries
Recommendations for Testing Radar-Based Collision Warning Systems on Heavy Equipment Ruff-TM | NIOSH Report of Investigations 9657, 2002 May; :1-17	2002	Publication (guidelines)	Traumatic injuries
Safety Analysis of Surface Haulage Accidents - Part 1 Randolph-RF; Boldt-CMK | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin May-June, 1997; :1-7	1997	Publication	Surveillance and training; Traumatic injuries
Safety Analysis of Surface Haulage Accidents - Part 2 Randolph-RF; Boldt-CMK | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin July, 1997; :6-7	1997	Publication	Surveillance and training; Traumatic injuries

Title	Year	Output Type	Strategic Goal
Technology News 484 - Devices to Monitor Blind Spots Near Large Haulage Equipment Ruff-TM | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 484, 2001 Jan :1-2	2001	Publication	Traumatic injuries
Test Results of Collision Warning Systems for Surface Mining Dump Trucks Ruff-TM | NIOSH Report of Investigations 9652, 2000 May; :44 pp	2000	Publication	Traumatic injuries
Test Results of Collision Warning Systems on Off-Highway Dump Trucks: Phase 2 Ruff-TM | NIOSH Report of Investigations 9654, 2001 Feb; :1-21	2001	Publication	Traumatic injuries
Proximity Warning Systems for Underground and Surface Mining NIOSH | Open Industry Briefing (Aug 9, 2005; Pittsburgh, PA). Approximately 125 attendees from government (MSHA), industry, labor, and academia	2005	Workshop, Seminar, or OIB	Traumatic injuries

Intermediate Outcome related to Reducing Machine-related Traumatic Injuries

Proximity Warning System for Reducing Injuries Pertaining to Mobile Mining Equipment

Description of Problem

Mining has always been a dangerous occupation. Although advances in technology can significantly reduce the risk of injury, that same technology can introduce new hazards. This is especially the case in underground and surface mines, where restricted workspace around larger, more productive mining machinery has resulted in serious traumatic injuries involving crushing and pinning. At underground mines, the risk involves workers in close proximity to remote-control continuous mining machines. At surface mines, the risk involves workers being injured while in close proximity to large haul trucks.

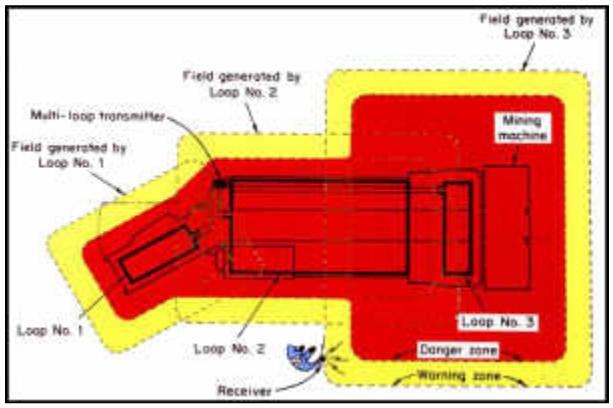


Illustration of a close proximity warning device on a continuous miner

Research and Development Activities

NIOSH collaborative research has led to better technology to warn miners who work around mobile equipment and in hazardous work areas. The Hazardous Area Signaling and Ranging Device (HASARD) offers a personal alert to the worker, along with remote shutdown capability. The HASARD system has patented features (e.g., a robust marker) to achieve greater reliability while minimizing nuisance alarms.

R&D Outputs and Transfer Activities

Several mining machine manufacturers have expressed interest in the application of the HASARD system. Workshops have been presented at the request of the Mine Safety and Health Administration (MSHA) and the United Mine Workers of America to help customers understand and consider application of the proximity warning technology.

A Cooperative Research and Development Agreement is pending to transfer HASARD technology to a South African firm (AIR SUN AUTO). NIOSH continues to work with MSHA and mining companies to field test the proximity warning technology.

Description of Intermediate Outcome

The HASARD system has been recently licensed to three firms. GeoSteering Mining Services is marketing its version of the system for use in underground mines. GeoSteering is also developing prototypes of its version of the NIOSH technology for use on surface haul trucks. ICG ADDCAR has adapted the system for use on highwall mining machines. Alliance Coal is presently prototyping the system for potential use on continuous mining machines.

Two licenses are pending: SSA Marine and DBT America Inc.

Outputs

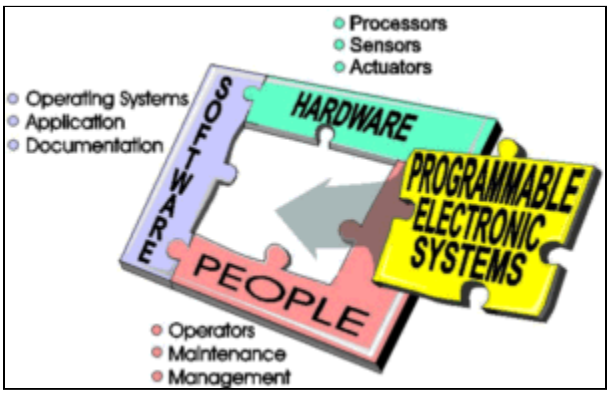
7 Outputs

Title	Year	Output Type	Strategic Goal
A Workplace Safety Device for Operators of Remote-Controlled Continuous Mining Machines Schiffbauer-WH | American Journal of Indus Med, Vol 36, Sup 1, 1999 Sep; :69-71	1999	Publication	Traumatic injuries
Active Promixity Warning Systems for Surface and Underground Mining Applications Schiffbauer-WH | Min Eng 54(12):40-48	2002	Publication	Traumatic injuries
An Active Proximity Warning System for Surface and Underground Mining Applications Schiffbauer-WH | SME Annual Meeting (Denver, CO; Feb 26-28, 2001), Preprint No. 01-117, SME, Inc., 2001 Feb; :1-8	2001	Publication	Traumatic injuries
An Environmentally Robust Proximity Warning System for Hazardous Areas Schiffbauer-WH; Mowrey-GL | in: Proceedings of the ISA Emerging Technologies Conference. Research, 2001, Triangle Park, North Carolina, Instrumentation, Systems, and Automation Society, Paper No. 2091; 2001; :10 pp	2001	Publication	Traumatic injuries
Mobile Machine Hazardous Working Zone Warning System Schiffbauer-WH; Ganoe-CW | U.S Patent #5,939,986 (granted Aug 17, 1999)	1999	Patent	Traumatic injuries
Non-directional Magnet Field-Based Proximity receiver with Multiple Warning and Machine Shutdown Capability Schiffbauer-WH | U.S. Patent #6,810,353 B2 (granted Oct 26, 2004)	2004	Patent	Traumatic injuries
Proximity Warning Systems for Underground and Surface Mining NIOSH | Open Industry Briefing (Aug 9, 2005; Pittsburgh, PA). Approximately 125 attendees from government (MSHA), industry, labor, and academia	2005	Workshop, Seminar, or OIB	Traumatic injuries

Intermediate Outcome related to Reducing Machine-related Traumatic Injuries

System Safety Best Practices to Reduce Injuries due to Malfunctioning Computerized Mining Systems

Description of Problem



Programmable electronics to monitor and control machine functions is increasingly common in mining systems. Computerized mining systems are very cost-effective and, when they function properly, can help reduce health and safety risk. When they randomly malfunction, however, they can introduce unexpected machine movements, resulting in workers being struck, pinned, or crushed. Although these incidents are rare, the consequences are quite severe. The mining industry does not have a formalized system safety process. As a result, safety is often addressed on an ad hoc basis.

Research and Development Activities

NIOSH collaborative research has developed a set of documents relating to the safety life cycle for programmable electronic mining systems based on International Electrotechnical Commission (IEC) Standard 61508 (part 1). They ensure that safety is considered with hardware, software, and human intervention all integrated together. The best practices are distilled from about 200 existing safety standards pertaining to programmable electronics.

R&D Outputs and Transfer Activities

Educational workshops held in the United States and Australia helped customers understand and apply the best practices. The Minerals Industry Safety and Health Centre of the University of Queensland (Australia) used the results for an academic course on Minerals Industry Risk Analysis.

Minerals Resources New South Wales (NSW) requested that two workshops and a keynote address be given at its 2001 Annual Electrical Safety Seminar. Minerals Resources NSW decided to start using the research as part of its approval process, as documented in a letter to the NIOSH Associate Director for Mining and Construction (January 21, 2002).

Description of Intermediate Outcome

Joy Mining Machinery, Inc., Forced Potato Mining Electronics, and DBT America, Inc. have integrated NIOSH research into their best practices/business plans.

Mining machine customers for Joy Mining Machinery, Inc. have specified that new equipment comply with the System Safety Best Practices.

The Mine Safety and Health Administration (MSHA) and the Pennsylvania Department of Environmental Protection have used the research results as part of the approval process for permits (http://www.msha.gov/techsupp/acc/sysafety/sysafety.htm).

NIOSH's National Personal Protective Technology Laboratory has used our methods and format for approval of programmable personal protective equipment.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Minerals Resources NSW (Australia) agreed to use the research for a rapid roadway development project, as documented in a letter to the NIOSH Associate Director for Mining and Construction (January 21, 2002). Minerals Resources NSW incorporated the research into the document "Policy for Implementing Safety Alert SA01-09 Radio Remote Control Mining Machines," as documented in a letter to the NIOSH Associate Director for Mining and Construction (July 21, 2001).

Outputs

16 Outputs

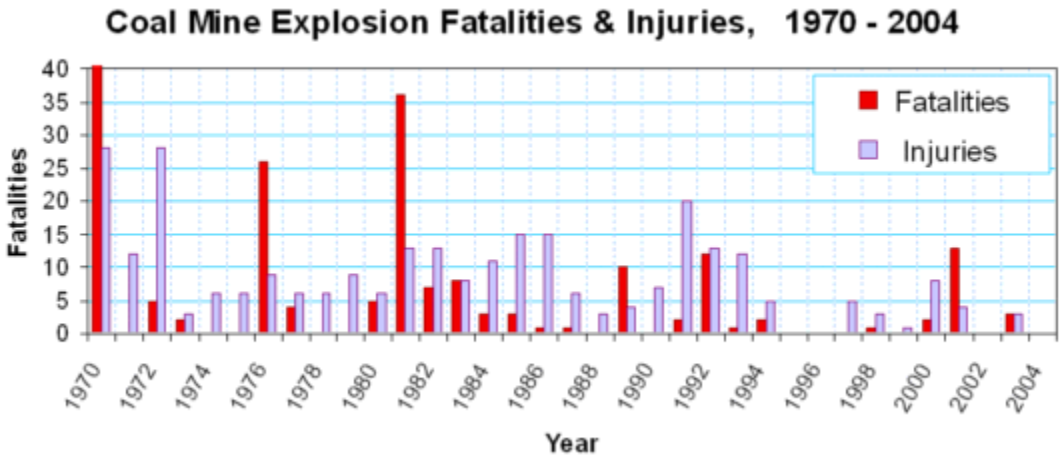
Title	Year	Output Type	Strategic Goal
A Complexity Assessment Methodology for Programmable Electronic Mining Systems Sammarco-JJ | Proc 20th Int System Safety Conf (Aug. 5-9, 2002; Denver, CO), 2002 Aug :177-186	2002	Publication	Traumatic injuries
Addressing the Safety of Programmable Electronic Mining Systems: Lessons Learned Sammarco-JJ | Proc 2002 IEEE 37th Industry Applications Society Ann Meet, Pittsburgh, Pennsylvania, 2003 :692-698	2003	Publication	Traumatic injuries
Programmable Electronic and Hard-Wired Emergency Shutdown Systems: A Quantified Safety Analysis Sammarco-JJ | In: Proceedings of the IEEE Industry Applications Society 40th Annual Meeting. Hong Kong. October 2005	2005	Publication	Traumatic injuries
Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts): Part 6: 5.1 System Safety Guidance Sammarco-JJ | NIOSH Publication No. 2005-150, Information Circular 9480, 2005 Aug; :1-87	2005	Publication	Traumatic injuries
Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts): Part 4: 3.0 Safety File Mowrey-GL; Fisher-TJ; Sammarco-JJ; Fries-EF | NIOSH Publication No. 2002-134, Information Circular 9461, 2002 May :1-57	2002	Publication (guidelines)	Traumatic injuries
Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts): Part 5: 4.0 Independent Functional Safety Assessment Sammarco-JJ; Fries-EF | NIOSH Publication No. 2003-138, Information Circular 9464, 2003 May; :1-35	2003	Publication (guidelines)	Traumatic injuries
Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts): Part 3: 2.2 Software Safety Fries-EF; Fisher-TJ; Jobes-CC | NIOSH Publication No. 2001-164, Information Circular 9460, 2001 Sep :1-45	2001	Publication (guidelines)	Traumatic injuries
Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts): Part 2: 2.1 System Safety Sammarco-JJ; Fisher-TJ | NIOSH Publication No. 2001-137, Information Circular 9458, 2001 Apr; :1-47	2001	Publication (guidelines)	Traumatic injuries
Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts): Part 1: 1.0 Introduction Sammarco-JJ; Fisher-TJ; Welsh-JH; Pazuchanics-MJ | NIOSH Publication No. 2001-132, Information Circular 9456, 2001 Apr; :1-10	2001	Publication (guidelines)	Traumatic injuries
Progress in Developing Software Safety Guidelines for the Mining Industry Sammarco-JJ | In: Gurgenci H, Hood M, eds. Proceedings of the Fourth International Symposium on Mine Mechanisation and Automation. Vol. 2 (Brisbane, Queensland, Australia), 1997; :B9-9 to B9-15	1997	Publication (guidelines)	Traumatic injuries
Safety Framework for Programmable Electronics in Mining Sammarco-JJ | Min Eng, 51(12), 1999 Dec; :30-33	1999	Publication (guidelines)	Traumatic injuries

Title	Year	Output Type	Strategic Goal
Safety Issues and the Use of Software-Controlled Equipment in the Mining Industry Sammarco-JJ; Kohler-JL; Novak-T; Morley-LA | IEEE Industry Applications Society 32nd Annual Meeting (Oct. 5-9, 1997; New Orleans, LA), 1997 Oct; :1-7	1997	Publication	Traumatic injuries
Safety Issues and the Use of Software-Controlled Equipment in the Mining Industry Sammarco-JJ; Kohler-JL; Novak-T; Morley-LA | In Lindsay PA, ed. Proceedings of the 1997 Australian Workshop on Industrial Experience With Safety Critical Systems and Software, Australian Computer Society: 1997; :25-32	1997	Publication	Traumatic injuries
Technology News 477 - A Systems Safety Approach for Programmable Electronics Sammarco-JJ | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 477, 1999 Aug; :1-2	1999	Publication (guidelines)	Traumatic injuries
Programmable Electronic Mining Systems (PEMS): Best Practice Recommendations Sammarco-JJ; Jobes-C | Joint NIOSH/MSHA Workshop (Sept. 26, 2002; Triadelphia, WV)	2002	Workshop, Seminar, or OIB	Traumatic injuries
Programmable Electronic Mining Systems: An Introduction to Safety Sammarco-JJ; Mowrey-G; Jobes-C; Welsh-J | Joint NIOSH/MSHA Workshop (Aug 17, 1999; Triadelphia, WV)	1999	Workshop, Seminar, or OIB	Traumatic injuries

Strategic Program Outcome for Mine Disasters

Preventing and Mitigating Mine Fires and Explosions

Mine fires and explosions remain a significant hazard in the mining industry. Since 2000, 18 underground mine fires have occurred in the United States. There were serious underground coal mine explosions in July 2000 at the Willow Creek Mine in Utah (2 fatalities and 8 injuries), in September 2001 at Jim Walter Resources´ No. 5 Mine in Alabama (13 fatalities and 3 injuries), and in January 2003 at the McElroy Mine in West Virginia (3 fatalities and 3 injuries).



The number of fatalities and injuries from mine fires and explosions declined greatly from 1970 to 1999. There were several "zero" years during the late 1990s despite a 700% increase in coal production during the same period. A rise in the number of injuries and fatalities since 2000 has prompted further NIOSH research into the causes and preventability of these accidents. These events, unlike other types of accidents where only a few workers are involved, often extend to every underground worker in the mine.

Since the mid-1990s, our research has led to the development of prevention, detection, control, and survivability technologies to reduce the probability of and fatalities from devastating fires and explosions. Many of these technologies have been adopted by the coal-producing and equipment manufacturing industry and are recognized in Mine Safety and Health Administration (MSHA) rulemaking. These technologies have also contributed to fire and explosion protection improvements in Australia and the Republic of South Africa.

Open industry briefings on mine fire preparedness conducted at NIOSH´s Lake Lynn Lab near Fairchance, PA, have enhanced the mining industry´s awareness of the dangers of underground mine fires. Realistic rescue and response training exercises for federal, state, and mine rescue teams at Lake Lynn have improved the effectiveness of rescue teams during numerous mine emergencies.

Development and implementation of a fire prevention checklist for profiling fire prevention and response capabilities at a mine site have played a key role in preventing and responding to incipient mine fires. NIOSH-developed discriminating fire sensors and optimum deployment strategies based on neural networks and combustion particle detection have reduced the number of false fire alarms when used in mining operations where smoke must be distinguished from normal diesel equipment exhaust.

Implementation of automatic fire suppression systems on conveyor belt drives and underground diesel storage areas has successfully controlled the rapid spread of belt fires within mine entries. NIOSH research on flammability of noise control materials in operator cabs led to MSHA´s acceptance of the American Society for Testing and Materials (ASTM) E-162 Radiant Panel Test as a major criterion in the selection and use of these materials.

Fire and explosion safety expertise, test equipment, and test procedures that we developed for the mining industry have been transferred to other industries. The consensus standard test methods of the ASTM International committee E27 on the Hazard Potential of Chemicals apply to numerous other industries besides mining. Many of NIOSH´s research findings were incorporated into the 2004 revised National Fire Protection Association (NFPA) mining fire protection standards (NFPA 120 (underground coal) and NFPA 122 (metal and nonmetal)).

NIOSH research to determine the risk of ignition of flammable atmospheres by laser-based optical and telecommunications equipment (fiber-optic networks) led to the development of ANSI standards governing the power thresholds for such lasers.

Postexplosion accident investigation and forensics tools were developed and used by MSHA to help understand and identify the root cause of explosions. Blast-resistant seals and performance test methods were developed at Lake Lynn Lab and implemented in partnership with MSHA. Passive and active explosion suppression techniques developed at Lake Lynn are routinely used in underground mines throughout the United States and in other countries, such as Australia and the Republic of South Africa.

Real-time, automated gob gas venthole monitoring and wireless data transmission permits continuous monitoring of individual gob gas ventholes to optimize methane drainage and reduce the potential for explosive methane-air mixtures.

NIOSH testing showed that safety for roof bolter operators could be improved by sweeping the area inby the bolter with a methanometer in addition to the machine-mounted methane monitor. This requirement was implemented in MSHA´s methane testing requirements.

Based on data obtained by NIOSH, the Pennsylvania Bureau of Deep Mine Safety permits the use of powered haulage to evacuate a mine in case of a main mine fan outage. Prior to NIOSH´s evaluation of worker safety during egress, the use of powered haulage was prohibited during main mine fan stoppages.

The mining industry has undergone tremendous advances in technology. These have provided opportunities to increase production and eliminate old hazards. However, they have often created new risks to workers. In many cases, these advances have introduced significant new fire and explosion safety hazards, such as increased methane emissions due to higher production levels. NIOSH research has helped improve fire detection and control and protection for mine workers against the hazards of underground mine fires and explosions.

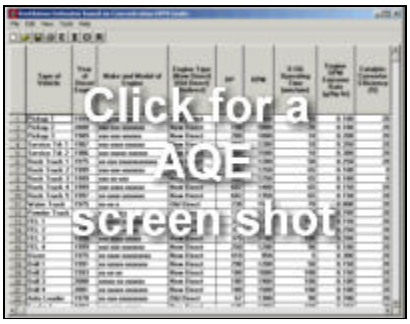
Intermediate Outcomes

- A Software Tool to Estimate the Required Ventilation Air Quantity for Mines Using Diesel Equipment
- Analysis of Fires in the Mining Industry
- Collaborative Research with Other Countries (1997-2002)
- Development and Evaluation of a Communication System for Mine Rescue Operations
- Development and Testing of a Smart Sensor System to Detect Mine Fires
- Development of a Fire Preparedness and Response Checklist for Mining Operations
- Evacuation of Underground Mine Workers During Main Fan Stoppages through Use of Electrically Powered Haulage
- Evaluation of a Directional Lifeline for Mine Evacuations
- Flammability Hazard Assessment of Noise Control Materials in Operator Cabs
- Forensic Investigations of Mine Fires and Explosions (1993-2005)
- Improved Methane Sampling During Roof Bolting
- Managing Methane in Underground Coal Mines
- Optimizing the Spacing of Fire Sensors in Mine Entries
- Protecting Coal Miners from Gob Explosions through Explosion-Resistant Mine Ventilation Seals (1993-2005)
- Realistic Training for Mine Emergency Responders
- Revised Standards for National Fire Protection Association (2002-2004)
- Transfer of Explosions and Fire Expertise and Test Procedures to Industry (1992-2005)
- Utilization of Large-Diameter Propeller Fans
- Ventilating Large-Opening Stone Mines using Novel Ventilation Techniques

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

A Software Tool to Estimate the Required Ventilation Air Quantity for Mines Using Diesel Equipment

Description of Problem



Underground workers in metal and nonmetal mines are exposed to various airborne contaminants, including diesel particulate matter (DPM). The operators of large-opening mines have long relied on natural ventilation and, in some cases, the use of auxiliary fans, in an attempt to reduce the concentration levels of these airborne contaminants. However, with the passage of regulatory standards in 2002 to limit DPM concentrations, the industry needed better tools to estimate the ventilation airflow requirements needed to meet the new statutory limits. An assessment of the ventilation airflow quantities required to meet the statutory DPM limits is the first step in developing engineering- based solutions to reduce worker exposure to this potential health hazard in the underground workplace.

Research and Development Activities

NIOSH developed a PC-based program called the Air Quantity Estimator (AQE) to meet this industry need. The air quantity estimates derived from the AQE are based on operating parameters of the mine´s underground diesel-powered equipment fleet. The results of the AQE analysis are used as the basis for designing engineering controls such as optimized mine layouts, proper ventilation fan selection, and stoppings to direct the ventilation airflow to the active working areas of the mine. In addition, the AQE analysis allows operators to identify vehicles that are high DPM sources. The engines in those vehicles can then be modified or upgraded to reduce their emissions, resulting in a lower total mine DPM load.

R&D Outputs and Transfer Activities

NIOSH researchers have demonstrated the AQE at several industry seminars and symposia. In addition, NIOSH has established partnerships with several large stone mine operators, including Coolspring Stone Supply, Inc., and Better Materials Corp. Hanson Aggregates' Whitney Mine and Coolspring Stone Supply, Inc.'s Coolspring Mine have used the AQE for their ventilation planning purposes.

Description of Intermediate Outcome

The AQE software program has been requested by 25 engineers from the stone industry. The program has been a direct benefit to operators in at least three known instances. One operator was able to identify that two diesel-powered vehicles accounted for 25% of the DPM emissions from the entire fleet operating in the mine. Also, two mines have exchanged diesel engines to improve their air quality based on insights provided by the AQE.

Outputs

3 Outputs

Title	Year	Output Type	Strategic Goal
A Computer Software Program that Estimates Air Quantity Requirements in Large Opening Stone Mines Robertson-SB; Grau-RH; Dolgos-JG; Mucho-TP | In: Ganguli R, Bandopadhyay S, eds. Mine ventilation: Proceedings of the 10th U.S./North American Mine Ventilation Symposium (Anchorage, Alaska, May 16-19, 2004). Leiden, Netherlands: Balkema, 2004 May; :363-369	2004	Publication	Mine disasters
NIOSH Ventilation Research Addressing Diesel Emissions and Other Air Quality Issues in Nonmetal Mines Grau-RH; Robertson-SB; Mucho-TP; Garcia-F; Smith-AC | 2002 SME Annual Meeting (Phoenix, Arizona; Feb 25-27, 2002). SME preprint 02-187. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :1-7	2002	Publication	Mine disasters; Respiratory diseases
Air Quantity Estimator (AQE) Grau-RH III; Robertson-SB; Dolgos-JG | NIOSH 2004 Jan; :software	2004	Software	Mine disasters; Respiratory diseases

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Analysis of Fires in the Mining Industry

Description of Problem

A mobile equipment fire

During 1990-1999, there were 912 reportable fires (i.e., those lasting 30 minutes or more) within the mining industry. These resulted in 439 injuries, 3 fatalities, and 44,108 lost workdays. The diversity of fire locations, material and equipment involved, and types of ignition sources reflect the complexity and diversity of today's mining industry. Fires can lead to catastrophic events with disastrous consequences. For fire prevention research to have a significant impact in reducing the incidence of fires and injuries, these incidents must be understood in greater detail.

Research and Development Activities

Statistics and detailed documentation provided by the Mine Safety and Health Administration (MSHA) and information provided by mining companies were used in this research. The data from all of the reportable fires were analyzed as to their location, combustible material, equipment involved, ignition source, detection and suppression methods, and several other factors. The findings resulted in a better understanding of the causes and hazards associated with mine fires and formed the basis for future fire research.

R&D Outputs and Transfer Activities

These detailed analyses have been reported in three NIOSH Information Circulars (ICs) and presented at fire safety conferences.

Description of Intermediate Outcome

These analyses have also been used by NIOSH researchers as a guide for developing long-range strategies for mine fire research and are directly impacting the focus of the NIOSH fire prevention research program. Research is being done in areas of high incidence and severity. This will have a significant impact on reducing the number of fires and resultant fatalities and injuries in the mining industry. The results are also being used by MSHA to pinpoint critical areas for fire protection and prevention and by the National Fire Protection Association to develop fire protection standards for the mining industry.

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
Analyses of Mobile Equipment Fires for All U.S. Surface and Underground Coal and Metal/Nonmetal Mining Categories, 1990-1999 De Rosa-MI | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevetnion, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publicaion No. 2004-105, IC 9467, 2004 Jan; :1-53	2004	Publication	Mine disasters; Surveillance and training
Analysis of Mine Fires for All U.S. Metal/Nonmetal Mining Categories, 1990-2001 De Rosa-MI | Pittsburgh, PA: U.S. Department of Heatlh and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-105, IC 9476, 2004 Nov; :1-52	2004	Publication	Mine disasters
Analysis of Mine Fires for All U.S. Underground and Surface Coal Mining Categories: 1990-1999 De Rosa-MI | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health , DHHS (NIOSH) Publication No. 2004-167, 2004 Sep; IC 9470; :1-36	2004	Publication	Mine disasters
Equipment Fires Cause Injuries De Rosa-MI | Coal Age 109(10), 2004; :28-31	2004	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Collaborative Research with Other Countries (1997-2002)

Description of Problem

As a result of research accomplishments by the NIOSH Pittsburgh Research Laboratory (PRL) in the area of fires and explosions, the worldwide scientific and engineering community has recognized our unique facilities and capabilities, especially the Lake Lynn Experimental Mine (LLEM).

Mining personnel and government researchers from both Australia and the Republic of South Africa have requested technical assistance from PRL to help address safety issues associated with underground fires and explosions in their coal mines. Two companies from Australia requested PRL's support in the performance testing of special high-strength seals for use in controlling spontaneous heating within sealed areas of coal mines. The Council for Scientific and Industrial Research (CSIR) of South Africa requested support in the full-scale testing of passive barriers to suppress propagating dust explosions in coal mines. In both cases, the LLEM was the only research facility in the world that could perform the required full-scale evaluations in a multiple-entry mining configuration. These joint research efforts were fully funded by Australia and the Republic of South Africa.

Research and Development Activities

Reliable seals are needed to control airflow to sealed areas prone to spontaneous combustion while containing blast effects should an explosion occur within the sealed area. Mining regulations in Queensland, Australia, require thorough evaluations of proposed seals and stoppings. Thus, the Australian companies contacted PRL for assistance. PRL researchers designed and conducted full-scale tests in the LLEM during 1997-1998 to evaluate the explosion-resistant characteristics of several mine seals, stoppings, and an overcast. The results were used by the Australians to assess the proper use of these ventilation structures in their coal mines.

The South Africans needed full-scale evaluations of their passive explosion barriers. These consist of a series of strategically placed bags of limestone rock dust suspended from the mine roof. This new passive barrier system relies on the pressure forces developed during an explosion to rupture the bags. This disperses the rock dust into the entry and suppresses the explosion. PRL researchers designed and conducted full-scale dust explosion tests in 1999-2000 to evaluate the barriers. Based on the results of these tests, the South Africans have implemented these barriers to protect workers in their coal mines.

R&D Outputs and Transfer Activities

Results of the joint seal evaluation research with Australia are documented in two NIOSH Reports of Investigations (RIs) in 1999 and 2002. Results from the joint research study with South Africa on the explosion barriers were presented at the Seventh International Mine Ventilation Congress in 2001 and published in the proceedings.

Description of Intermediate Outcome

Based on the successful conclusions to these joint projects and the implementation of new regulations, these seals and barriers are now being used to protect miners from underground explosions in both Australia and the Republic of South Africa.

Outputs

3 Outputs

Title	Year	Output Type	Strategic Goal
Evaluation of Explosion-Resistant Seals, Stoppings, and Overcast for Ventilation Control in Underground Coal Mining Weiss-ES; Cashdollar-KL; Sapko-MJ | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centrs for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2003-104, Report of Investigations 9659, 2002	2002	Publication	Mine disasters
Evaluation of Reinforced Cementitious Seals Weiss-ES; Cashdollar-KL; Mutton-IVS; Kohli-DR; Slivensky-WA | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 99-136, Report of Investigations 9647, 1999	1999	Publication	Mine disasters
Evaluation of the Bagged Stone Dust Barrier Effectiveness in a Bord and Pillar Mine Du Plessis-JJL; Weiss-ES; Cashdollar-KL | In: Wasilewski S, ed., Proceedings of the Seventh International Mine Ventilation Congress (June 17-22, 2001, Crakow, Poland), chapter 81, :573-580	2001	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Development and Evaluation of a Communication System for Mine Rescue Operations

Description of Problem

When a rescue team explores complex underground passageways, such as those found in mines, a lifeline and reliable communication system is essential. Current mine rescue team communication technology is based on a sound-powered phone system developed in 1946 that provides communication from only one team member to one other location, the underground fresh air base. Mine rescue teams requested a reliable system that would permit communication among all team members, the fresh air base, and the surface command center. Existing communication systems are not readily adaptable for underground mine use.

Rescue team members testing the Res-Q-Com system

Research and Development Activities

NIOSH and Transtek, Inc. (Pittsburgh, PA), collaborated in developing and evaluating the Ron Conti Res-Q-Com System. The Res Q-Com is a self-contained, portable, battery-operated system that provides voice communication and a lifeline for rescue teams, such as those summoned for an underground mine emergency. It consists of a mobile reel, 1,000-foot lifeline, and electronics, repeaters, and handheld radios. The system provides a choice of communication modes that include team members only, the team members and an underground fresh air base, the fresh air base and a surface command center, or all of the above. A team member can also leave the team lifeline and explore the underground surroundings for a distance of several hundred feet while retaining communications with the team and fresh air base.

R&D Outputs and Transfer Activities

The Res-Q-Com system was evaluated during training exercises with mine rescue teams at Lake Lynn Lab. The findings were presented at mining conferences, workshops, and operating mines.

Description of Intermediate Outcome

The Res-Q-Com system is now commercially available. It represents a significant advancement in rescue technology for the mining environment. The system was highlighted in *International Longwall News* (December 19, 2003) and in *Coal Age* magazine (February 2004). It is named after the NIOSH researcher, now deceased, who pioneered its development.

Outputs

1 Output

Title	Year	Output Type	Strategic Goal
Fire Response Preparedness for Underground Mines Conti-RS; Chasko-LL; Wiehagen-WJ; Lazzara-CP | Pittsburgh, PA, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. , NIOSH IC 9481	2005	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Development and Testing of a Smart Sensor System to Detect Mine Fires

Description of Problem

There is a need to provide early and reliable mine fire detection in the event of a mine fire. The discrimination of mine fires from nuisance signatures, such as emissions from diesel equipment, flame-cutting and welding activities, and battery-charging operations, is an ongoing problem for early and reliable mine fire detection. Carbon monoxide sensors are subject to false signals from diesel equipment nuisance emissions and hydrogen cross-interference from battery-charging operations. Smoke sensors are subject to false signals from diesel equipment and rock-dusting operations.

Sensors used to discriminate a mine fire from nuisance emissions

Research and Development Activities

NIOSH developed a multiple-type mine fire sensor approach to nuisance signal discrimination. A neural network was constructed for a base set of four fire sensor types. Mine fire discrimination experiments were done with coal, belt, diesel fuel, and wood fires in the presence of diesel emissions in the Pittsburgh Research Laboratory's (PRL) Safety Research Coal Mine. From a training set of experiments, a neural network algorithm was developed. The trained neural network was evaluated with a real-time application to additional mine fire experiments.

R&D Outputs and Transfer Activities

Results from this research were transferred to the mining community through publications and conferences. In addition, a mine fire detection workshop was held in September 2003 at PRL.

Description of Intermediate Outcome

The sensors and neural network are currently being evaluated at Foundation Coal's Cumberland coal mine in Pennsylvania as part of a demonstration project. Mine monitoring software was provided by Conspec Controls. The sensors are located in a high-vehicular traffic area in which rock dusting occurs occasionally. This research will provide an impetus to sensor manufacturers to apply state-of-the-art software analysis methods to discriminatory mine fire detection for improved early and reliable mine fire detection.

Outputs

15 Outputs

Title	Year	Output Type	Strategic Goal
CFD Analysis of Mine Fire Smoke Spread and Reverse Flow Conditions Edwards-JC; Hwang-CC | Proc Eighth U.S. Mine Ventilation Symposium. Rolla, MO; University of Missouri-Rolla, Press, Rolla, Missouri, 1999 Jun; :417-422	1999	Publication	Mine disasters
CFD Modeling of Smoke Reversal Hwang-CC; Edwards-JC | Proc International Conference on Engineered Fire Protection Design (Jun 11-15, 2001; San Francisco, CA), Bethesda, MD: Society of Fire Protection Engineers, Inc. :376-387	2001	Publication	Mine disasters
Discriminatory Mine Fire Source Detection Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | In: Wasilewski S, ed. Proceedings of the Seventh International Mine Ventilation Congress (Jun 17-22, 2001; Krakow, Poland) Ch 91, 2001; :649-655	2001	Publication	Mine disasters
In Mine Evaluation of Discriminating Mine Fire Sensors Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | In: E. DeSouza, ed. Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (June 8-12, 2002, Kingston, Ontario, Canada). A. A. Balkema Publishers, Lisse, Netherlands; :527-532	2002	Publication	Mine disasters
Mine Fire Detection in the Presence of Diesel Emissions Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | Chemical and Physical Process of Combusion. The Fall Technical Meeting of the Eastern States Section of the Combustion Institute (Oct 10-13, 1999; Raleigh, NC), North Carolina State University; :89-92	1999	Publication	Mine disasters
Mine Fire Detection in the Presence of Diesel Emissions Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | Proc Eighth U.S. Mine Ventilation Symposium. Rolla, MO: University of Missouri-Rolla, Press, 1999 Jun; :295-301	1999	Publication	Mine disasters
Mine Fire Detection in the Presence of Diesel Emissions Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | Journal of the Mine Ventilation Society of South Africa. 2000 53(2); :66-71	2000	Publication	Mine disasters
Mine Fire Source Discrimination Using Fire Sensors and Neural Network Analysis Edwards-JC; Friel-GF; Franks-RA; Lazzara-CP; Opferman-JJ | Combustion Fundamentals and Applications - Proceedings of the 2000 Technical Meeting of the Central States Section of the Combustion Institute (April 17-18, 2000, Indianapolis, IN); :207-211	2000	Publication	Mine disasters
Multiple Type Discriminating Mine Fire Sensors Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | Trans Soc Min Metal Explor, Transactions, Vol 314, 2003 Dec; :166-171	2003	Publication	Mine disasters
Neural Network Application to Mine-Fire Diesel-Exhaust Discrimination Friel-GF; Edwards-JC | In: De Souze E, Ed. Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Jun 8-12, 2002; Kingston, Ontario, Canada). A. A. Balkema Publishers, Lisse, Netherlands; :533-538	2002	Publication	Mine disasters
Overview of Mine Fire Detection Edwards-JC | Proc Second International Conference on Fire Research and Engineering (August 3-8, 1997; Bethesda, MD), 1998 Aug :489-499	1998	Publication	Mine disasters

Title	Year	Output Type	Strategic Goal
Real-time Neural Network Application to Mine Fire - Nuisance Emissions Discrimination Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | In: Ganguli-R and Bandopadhyay-S, eds. Mine Ventilation: Proc 10th U.S./North American Mine Ventilation Symposium (May 16-19, 2004, Anchorage, AK). A. A. Balkema Publishers, Lisse, Netherlands; :425-431	2004	Publication	Mine disasters
Technology News 498 - Multiple Fire Sensors for Mine Fire Detection and Nuisance Discrimination NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 498, 2002 Sep :1-2	2002	Publication	Mine disasters
Underground Fire Detection and Nuisance Alarm Discrimination Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | Coal Age, Intertec Publishing, 106(7), 2001 Jul; :70-72	2001	Publication	Mine disasters
Fire Detection Technology Workshop Workshop conducted for 43 participants from coal companies, sensor manufacturers, MSHA, the UMWA, a university, and NIOSH (Pittsburgh Research Laboratory, Sept 4, 2003)	2003	Workshop, Seminar, or OIB	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Development of a Fire Preparedness and Response Checklist for Mining Operations

Description of Problem

Fires are still too common an occurrence in the U.S. coal mining industry and a major concern for those who work underground. Statistics from the Mine Safety and Health Administration (MSHA) show that 152 reportable fires (i.e., those lasting 30 minutes or more) occurred at underground coal mines during 1990-1999. Several recent coal mine fires have resulted in sealing the mines for long periods. This resulted in loss of jobs and worker stress and greatly impacted the economic health of the community.

Research and Development Activities

To address this problem, an underground coal mine fire preparedness and response checklist was developed and evaluated. It was field tested under a Cooperative Research and Development Agreement with Twentymile Coal Co. (Oak Creek, CO) and at several other operating mines. The checklist is a data collection instrument for profiling the fire prevention and response capabilities of a mine site. It encompasses conditions, procedures, and equipment that often have been identified as the main or contributing causes of underground coal mine fires. Topics covered include combustible materials, water systems, fire detection and suppression systems, firefighting equipment, mine rescue teams, and fire brigades.

R&D Outputs and Transfer Activities

The checklist has been highlighted in presentations at mining conferences, fire prevention workshops, and mine sites. A NIOSH Information Circular (IC) was also published in 2000. More than 200 copies of the IC have been distributed and continue to be requested.

Description of Intermediate Outcome

Coal mines are using the checklist to assist in their fire prevention programs and enhance their fire response capabilities. MSHA has adopted portions of the checklist for its training materials to prevent mine fires and for conducting mine fire prevention audits. The checklist was highlighted in *International Longwall News* (August 25, 2003).

Outputs

1 Output

Title	Year	Output Type	Strategic Goal
An Underground Coal Mine Fire Preparedness and Response Checklist: The Instrument Conti-RS; Chasko-LL; Lazzara-CP; Braselton-G | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 2000-144, IC 9452, 2000 Aug; :151 pp	2000	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Evacuation of Underground Mine Workers During Main Fan Stoppages through Use of Electrically Powered Haulage

Description of Problem

A main mine fan outage can lead to a rapid increase in methane levels in the mine because the dilution effect of ventilating air is lost. Mine personnel must be evacuated due to the potential for a mine explosion. Powered haulage can be used to transport workers quickly from the working areas of the mine to the surface. However, Pennsylvania state mining law prohibited the use of powered haulage during a main mine fan outage. Many mining companies challenged this law, arguing that it would take miners longer to evacuate the mine traveling on foot. Studies were needed to assess how much methane accumulates in haulageways when a main mine fan stops.

A researcher installs a methane monitoring device

Research and Development Activities

NIOSH performed studies in four Pennsylvania underground mines to develop criteria for evaluating the rate and level of methane concentration increases along haulageways where workers would travel while leaving a mine after a fan stoppage. The fan stoppages at the mines lasted from 3 to 5 hours. Guidelines were developed for the use of the sampling instruments and the selection of sampling locations. Methane monitors, equipped with data loggers, were placed in the mine before the fan was stopped and retrieved from the mine after the fan was restarted. The data showed that measurable increases in methane occurred at some of the mining faces during fan stoppage. However, methane increases along haulageways were minimal during the 3- to 5-hour fan stoppages.

R&D Outputs and Transfer Activities

The results were communicated to the Pennsylvania Bureau of Deep Mine Safety, which had prohibited the practice of using powered haulage to evacuate a mine during main fan stoppages. The findings at each of the individual mine test sites were also provided to the specific mines. They were presented at several national and international mining conferences and were published in a peer-reviewed journal.

Description of Intermediate Outcome

The Pennsylvania Bureau of Deep Mine Safety used the data obtained by NIOSH to evaluate the safety of workers leaving a mine following a fan stoppage. Based on the findings of these studies, the agency adopted a policy of granting permission to Pennsylvania mines to use powered haulage during main mine fan shutdowns on a case-by-case basis. Several Pennsylvania mines have been able to obtain this approval.

NIOSH sampling procedures developed during this study provide a way for underground coal mines to evaluate the rate and level of methane concentrations along powered haulageways following a stoppage of the main mine fan.

Outputs

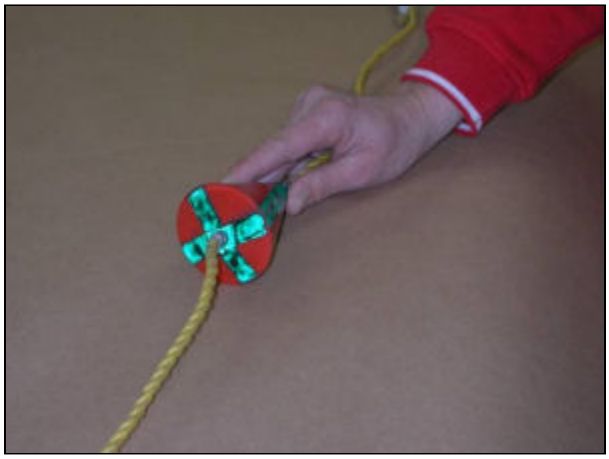
2 Outputs

Title	Year	Output Type	Strategic Goal
Safety Concerns Associated With the Use of Electrically Powered Haulage to Remove Workers from Mines During Main Fan Stoppages Taylor-CD; Timko-RJ; Thimons-ED; Zimmer-JA | In: De Souze E, ed. Proc North American/Ninth U.S. Mine Ventilation Symposium (Jun 8-12, 2002; Kingston, Ontario, Canada). Lisse, The Netherlands: A. A. Balkema; 2002 Oct; :649-653	2002	Publication	Mine disasters
Safety Concerns Associated With the Use of Electrically Powered Haulage to Remove Workers from Mines During Main Fan Stoppages Taylor-CD; Timko-RJ; Thimons-ED; Zimmer-JA | J Mine Vent Soc S Afr 56(1), Jan/Mar 2003; :6-10	2003	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Evaluation of a Directional Lifeline for Mine Evacuations

Description of Problem



Directional lifeline

Evacuating an underground mine during a fire or after an explosion can be hard due to the long distances involved and potential smoke-filled passageways that greatly limit visibility. Although some mines use lifelines to guide escaping miners, the miners can become disoriented in the smoke and travel in the wrong direction.

Research and Development Activities

To address this issue, NIOSH evaluated a commercially available directional lifeline (CAB Products) during evacuation exercises through nontoxic, smoke-filled entries in the Lake Lynn Experimental Mine and in operating mines. The rope lifeline has cones spaced at regular intervals along its length. If the miner's hand slides over the cone, he or she is going in the correct direction. If the hand is blocked by the cone, he or she is heading in the wrong direction. More than one cone can be located just before an obstacle, such as a mine door. Since 2000, the directional lifeline was chosen by more than 1,300 miners during evacuation exercises as the best means of guiding them to safety through smoke-filled passageways.

R&D Outputs and Transfer Activities

The findings on the directional lifeline were presented at mining conferences, fire prevention and response workshops, mine rescue competitions, and operating mines.

Description of Intermediate Outcome

As a result of this work, several mines have installed directional lifelines in their escapeways. The Mine Safety and Health Administration has required directional lifelines in escapeways of underground coal mines that are ventilated with return air from working sections that are ventilated with belt entry air (30 CFR 75.380(n)). The directional lifeline was highlighted in *International Longwall News* (March 21, 2005).

Outputs

2 Outputs

Title	Year	Output Type	Strategic Goal
Emerging Technologies: Aiding Responders in Mine Emergences and During the Escape From Smoke-Filled Passageways Conti-RS | Proc Northwest Mining Association 107th Annual Meeting, Exposition and Short Courses (December 3-7, 2001; Spokane, WA); :14 pp	2001	Publication	Mine disasters; Surveillance and training
Technologies for Today's Mine Emergency Responders Conti-RS; Chasko-LL | International Journal of Emergency Management, 1(1); :13-29	2001	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Flammability Hazard Assessment of Noise Control Materials in Operator Cabs

Description of Problem

In 2001, the Mine Safety and Health Administration (MSHA) promulgated regulations requiring the use of noise control materials within the mining industry, in particular within the operator cabs of large mining equipment, to reduce the incidence of injuries resulting in hearing loss. Although the new regulations provided specific acoustic criteria for the selection and use of these materials, little guidance was provided with regard to their flammability and fire resistance. The limited flammability data available were mainly from small-scale flammability testing, such as SAE J369 and UL 94, and were not considered to be indicative of end-use conditions.

Testing the flammability of noise materials in laboratory tunnel

Research and Development Activities

In order to assess the potential hazards from fires involving these materials, both intermediate- and large-scale experiments were conducted. Intermediate-scale experiments were conducted in a horizontal tunnel under conditions of forced airflow. Large-scale experiments were conducted by lining the interior walls and roof of a full-size cab. A total of 21 different materials were evaluated and rated using a heat parameter (HP), which is the ratio of maximum fire heat output to enclosed air volume. The HP values were then correlated with flame spread indices obtained at MSHA's Approval and Certification Center using the standard American Society for Testing and Materials (ASTM) E-162 Radiant Panel Test. The experimental program confirmed that small-scale flammability tests were grossly inadequate and that the standard ASTM E-84 tunnel test was not reliable for predicting the fire hazard of these materials.

R&D Outputs and Transfer Activities

Research results were presented at the Fire and Materials Conference in January 2003 and published in the conference proceedings. Results have also been presented at NIOSH technology transfer seminars.

Description of Intermediate Outcome

MSHA subsequently adopted a set of guidelines for selecting these materials that addresses the material flammability and fire resistance and cites NIOSH's work in support of its guidelines. Copies of the NIOSH technical paper describing the experimental program, the results, and the selection guidelines recommended by MSHA are made available to the mining industry for its use in selecting noise control materials that satisfy both acoustic and fire-resistance criteria.

Outputs

1 Output

Title	Year	Output Type	Strategic Goal
Flammability of Noise Abatement Materials Used in Cabs of Mobile Mining Equipment Litton-CD; Mura-KE; Thomas-RA; Verakis-HC | Proc: Fire & Materials 2003. London: Interscience Communications, 2003 Feb; :297-306	2003	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Forensic Investigations of Mine Fires and Explosions (1993-2005)

Description of Problem

The mining and scientific communities have long recognized the unique facilities and capabilities of the NIOSH Pittsburgh Research Laboratory (PRL) in fire and explosion research. PRL scientists continue to receive requests from a variety of research organizations, industries, and government agencies to provide technical assistance related to the fire and explosion hazards of dusts, gases, liquids, and explosives. In particular, the Mine Safety and Health Administration (MSHA) has often requested help from PRL in its forensic investigations of mine ignitions, fires, and explosions. Identification of the root cause of these accidents often requires detailed analysis of small samples of residue and a basic understanding of the mechanisms of dust and gas ignitions and explosion propagation.

Collection of post-explosion dust samples for forensic analysis

Research and Development Activities

PRL has used optical microscopes, a scanning electron microscope (SEM), and thermodynamic models to aid MSHA in accident investigations. The SEM and auxiliary x-ray elemental analysis system have been used to identify types of particles and whether particles have been heated in explosions. The following are examples of PRL assistance to MSHA:

1. The Elmo No. 5 coal mine in Kentucky had a methane explosion in 1993 that killed one miner and injured another. Articles of the miner's clothing and a charred lighter were examined at PRL using optical macro and microscopic techniques. MSHA used our analyses to conclude that the ignition had been caused by prohibited smoking.
2. An ignition event at the Anderson limestone mine in Tennessee in 2000 was attributed to the frictional ignition of a rock inclusion that might contain sulfur. MSHA requested PRL to examine a sample of the suspect rock. PRL used optical microscopy, the SEM facility, and a simple heating test to identify the presence of elemental sulfur. Sulfur is known to be easily ignited and was the evident cause of the mine incident.

3. Multiple explosions occurred at the Pinnacle Mine in West Virginia in September-October 2003. MSHA requested that PRL investigate a borehole cover plate for evidence of a possible lightning strike and an explosion within the borehole. No obvious evidence of a lightning strike was found, but soot was found on the inside of the borehole cover plate.

R&D Outputs and Transfer Activities

The results of the PRL analyses were reported to MSHA. MSHA then used the information as part of its accident investigation reports. Additional information on the postexplosion observations at PRL's Lake Lynn Experimental Mine have been reported in various publications.

Description of Intermediate Outcome

PRL has helped MSHA determine the root causes of mine explosion accidents. The resulting MSHA investigation reports help prevent future accidents.

Outputs

2 Outputs

Title	Year	Output Type	Strategic Goal
Coal Dust Inerting and Postexplosion Dust Sampling Research in a 1-M3 Laboratory Chamber and an Experimental Mine Cashdollar-KL; Going-JE | In: Proceedings of the 2003 Technical Meeting of the Eastern States Section of the Combustion Institute (The Pennsylvania State University, University Park, PA, October 26-29, 2003). Pittsburgh, PA: The Combustion Institute, 2003; :97-100	2003	Publication	Mine disasters
Experimental Mine and Laboratory Dust Explosion Research at NIOSH Sapko-MJ; Weiss-ES; Cashdollar-KL; Zlochower-IA | J Loss Prev Process Ind 2000 May; 13(3) :229-242	2000	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Improved Methane Sampling During Roof Bolting

Description of Problem

Roof bolter operator making a methane check

Federal regulations require that face methane samples must be taken at least once every 20 minutes within 1 foot of the working face during the coal mining and roof bolting process. On deep-cut sections, the freshly cut face can be 40 feet away from the last row of bolts. Because workers at roof bolters are forbidden to move forward beyond the last row of bolts, they cannot walk forward to sample for methane at the face. They must attach a methanometer to a long pole or a cart with a long handle. These pole and cart methods are difficult and time-consuming. As a result, face methane readings are often taken in an inefficient manner or are not taken at all.

Research and Development Activities

NIOSH was approached by both industry (Bituminous Coal Operators' Association (BCOA)) and labor (United Mine Workers of America (UMWA)) to investigate alternative approaches to methane sampling. NIOSH conducted a study on alternative methods for measuring methane levels during bolting operations, especially when bolting in deep cuts. Accident reports showed that methane gas was released at the face and from roof bolt holes. NIOSH testing was performed in a full-scale simulated continuous miner face gallery equipped with a model roof bolter. Gas was released from the face and from roof bolt holes and then measured with methanometers placed on the model bolter and between the bolter and the face. A variety of practical mining configurations was simulated. The results showed that worker safety could be improved if a combination of (1) a portable monitor, mounted on a short pole, was used to "sweep" the area about 10 feet inby the bolter and (2) a roof bolter-mounted monitor was used to measure gas near the bolt holes. This system of face methane monitoring during roof bolting was easier and provided a greater degree of safety than the required single 20-minute reading at the immediate working face.

R&D Outputs and Transfer Activities

A meeting was held in Washington, DC, where NIOSH researchers presented the findings to the BCOA and UMWA. The results were also communicated directly to the Mine Safety and Health Administration (MSHA). NIOSH also presented the findings at several mining conferences and published them in a peer-reviewed journal.

Description of Intermediate Outcome

The UMWA and BCOA jointly recommended that MSHA amend current methane sampling requirements during roof bolting based on the results of the NIOSH study. MSHA found the results of the NIOSH study compelling enough that the final rule was published on July 7, 2003 (Federal Register, Vol. 68, No. 129, pp. 40132-40138).

Outputs

2 Outputs

Title	Year	Output Type	Strategic Goal
Comparison of Methane Concentrations at a Simulated Coal Mine Face During Bolting Taylor-CD; Thimons-ED; Zimmer-JA | In: Tien JC, ed. Proceedings of the Eighth U.S. Mine Ventilation Symposium, Rolla, MO: University of Missouri-Rolla Press, 1999; :171-178	1999	Publication	Mine disasters
Comparison of Methane Concentrations at a Simulated Coal Mine Face During Bolting Taylor-CD; Thimons-ED; Zimmer-JA | J Mine Vent Soc S Afr, 52(2),1999 Apr; :48-52	1999	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Managing Methane in Underground Coal Mines

Description of Problem

Gob gas venthole with pump and methane monitoring system

Mine operators have been unable to quantitatively forecast the potential for hazardous accumulations and emissions of methane under varying mining conditions. This has contributed to circumstances that led to 110 U.S. coal miner deaths in explosions since 1980. Recent methane explosions occurred (1) in West Virginia in 2003 (3 fatalities and 3 injuries), (2) in Alabama in 2001 (13 fatalities and 3 injuries), and (3) in Utah in 2000 (2 fatalities and 8 injuries). The presence of combustible concentrations of methane is also indicated by the occurrence of frictional ignitions. They are still relatively common in U.S. coal mines and averaged about 60 annually from 1995 to 2004. The Black Warrior Basin in Alabama has consistently led the nation in annual frictional ignitions (as high as 50% in some years) since the beginning of NIOSH industry surveys.

Research and Development Activities

NIOSH researchers conducted reservoir and rock mechanics modeling as part of an effort to develop a comprehensive, mine-wide predictive model to quantify methane emissions in advance of mining. At a cooperating Pennsylvania mine, the modeling of gob gas movement revealed inefficiencies in the removal of methane by gob gas ventholes using the mine's traditional borehole configurations. Modeling showed that a modification to the venthole completion design would enhance methane drainage and potentially reduce the amount of gas entering the mine workings. Improvements in gob gas venthole performance were achieved through the use of automated gob gas venthole monitoring and data acquisition systems. NIOSH scientists sampled the mined coalbed and adjacent strata at a mine in Alabama with a history of frictional ignition problems. Mineralogical analysis confirmed that a hard, quartz-rich floor rock was the source of frictional ignitions when contacted by the mining bit.

R&D Outputs and Transfer Activities

The reservoir modeling findings have been presented at conferences, published in conference proceedings, and reviewed with mine management. The NIOSH-developed remote gob gas venthole monitoring and cellular telephone based real time data transmission system was presented and published in conference proceedings. It has been discussed with a vendor that is considering offering components of the system as a service to mine operators. The analytical findings for the Alabama floor rock were discussed with mine management, and potential remedial measures were reviewed.

Description of Intermediate Outcome

The NIOSH longwall gob gas flow modeling research results have led a Pennsylvania mine operator to adopt our recommendations for gob gas venthole completion configurations for its longwall mines. The NIOSH-developed remote gob gas venthole monitoring system is currently in use on several gob vent boreholes in Pennsylvania.

Outputs

3 Outputs

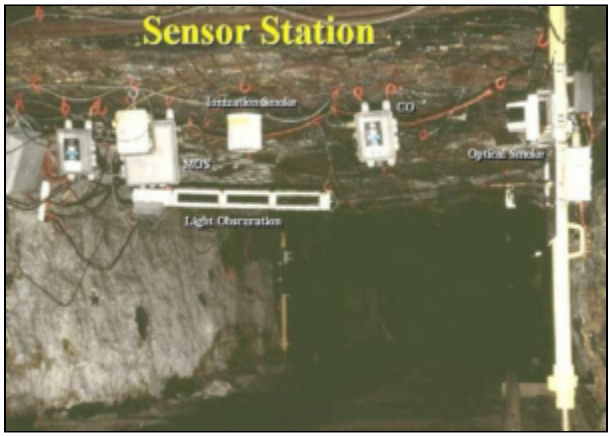
Title	Year	Output Type	Strategic Goal
Application of Numerical Models to Investigate Permeability Changes and Gas Emissions Around Longwall Mining Panels Esterhuizen-G; Karacan-CO | Proceedings of the 40th US Rock Mechanics Symposium (Anchorage, Alaska), CD-ROM, paper 05-744; :13 pp	2005	Publication	Mine disasters
Numerical Analysis of the Impact of Longwall Panel Width on Methane Emissions and Performance af Gob Gas Ventholes Karacan-CO; Diamond-WP; Esterhuizen-GS; Schatzel-SJ | In: Proceedings of the International Coalbed Methane Symposium (Tuscaloosa, AL; May 18-19, 2005). University of Alabama, 2005; :28 pp	2005	Publication	Mine disasters
Remote Gob Gas Venthole Monitoring and Cellular Telephone-Based Real-Time Data Transmission System Garcia-F; Diamond-WP; Marshall-JK | In: De Souze E, ed. Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Kingston, Ontario, Canada). Lisse, Netherlands: Balkema, 2002; :324-329	2002	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Optimizing the Spacing of Fire Sensors in Mine Entries

Description of Problem

The use of belt air directed toward the working face of a coal mine requires the installation of carbon monoxide (CO) sensors. CO and smoke sensor spacing guidelines required in belt entries were not established for low airflows less than 50 feet per minute. The Mine Safety and Health Administration (MSHA) required this information for the development of belt air regulations when belt air is used to ventilate the working face of a coal mine.



Sensors used to monitor smoke and CO movement from a mine fire

Research and Development Activities

Experiments were conducted to determine the carbon monoxide sensor alarm time response to diesel fires with intensities between 30 and 495 kW under zero airflow in the Pittsburgh Research Laboratory's Safety Research Coal Mine. It was found that the sensor spacing required to provide a 14-minute warning for a small 30-kW fire was 350 feet. It had been previously established that 14 minutes was required for a small flaming coal fire to ignite a conveyor belt.

R&D Outputs and Transfer Activities

Research results were published in the Proceedings of the Sixth International Mine Ventilation Congress held in Pittsburgh, PA, in 1997.

Description of Intermediate Outcome

The research led to rulemaking by MSHA for atmospheric mine monitoring in a belt air course, as established in 30 CFR 75.351(e)(3), effective July 1, 2004: "In areas along each belt entry where air velocities are less than 50 feet per minute, the sensor spacing must not exceed 350 feet." This sensor spacing for an atmospheric monitoring system is required in a belt entry used to ventilate a working face, as specified in 30 CFR 75.350(b)(1). As a result of this impact, early mine fire detection will be ensured in a belt entry when belt entry air is used to ventilate a mine working face. This research has contributed to a rule in the Code of Federal Regulations, which provides a safe working environment for underground miners.

Outputs

1 Output

Title	Year	Output Type	Strategic Goal
Mine Fire Detection Under Zero Airflow Conditions Edwards-JC; Friel-GF; Franks-RA; Opferman-JJ | Proceedings of the 6th International Mine Ventilation Congress, Chapter 52, Ramani RV, ed., Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 1997 Feb; :331-336	1997	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Protecting Coal Miners from Gob Explosions through Explosion-Resistant Mine Ventilation Seals (1993-2005)

Description of Problem

Ventilation seals are used extensively in mining to safely isolate old workings and fire areas from the active sections of a mine to protect underground workers from explosions. Without reliable seal designs, miners' lives could be in jeopardy from the consequences of an underground explosion.

NIOSH researchers inspecting a mine seal before hydrostatic testing

Research and Development Activities

The NIOSH Pittsburgh Research Laboratory (PRL), in partnership with national and international mine operators, seal manufacturers, and the Mine Safety and Health Administration (MSHA), has developed and evaluated numerous new and innovative seal designs. The main focus of the effort was to develop mine sealing technologies for use during mine emergencies, within unique geological conditions in the mine, and/or for generalized mine gob sealing.

All new seal designs were performance-tested in PRL's Lake Lynn Experimental Mine (LLEM) for strength characteristics against explosions and for air leakage resistance before and after an explosion. If the seal design met the requirements of the program as set forth at 30 CFR 75.335, MSHA then deemed the seal design acceptable for use in underground coal mines. Twenty-seven different seal designs have been developed and evaluated in the LLEM.

R&D Outputs and Transfer Activities

The results of this research have been distributed through reports to MSHA, publications, and workshops. NIOSH researchers have collaborated closely with manufacturers and mine operators to translate this research into practice. The seal designs that have been developed and proven in the LLEM have been deemed suitable by MSHA and are now being built and used daily in the United States and abroad.

Description of Intermediate Outcome

More than 35,000 seals based on designs tested in the LLEM have been installed in commercial coal mines in recent years. For example, Strata Mine Products has installed more than 5,000 seals since June 1999. This novel seal design, which consists of a locking, solid-concrete-block wall preloaded on the sides and near the mine roof with packsetter pumpable grout bags, is an important item in this company's product line. Burrell Mining Products has successfully commercialized a new lightweight concrete block seal design based on results from full-scale seal research in the LLEM. This design is easier to build, resulting in less musculoskeletal stress typically associated with conventional heavy solid-concrete-block designs and handling techniques. Since NIOSH's evaluation of the new seal design in June 2002, Burrell has been averaging about 70 seal installations per month.

A gob gas explosion occurred on or about June 16, 1995, where lightning initiated an explosion in a sealed section of the Gary 50 Mine in Pineville, WV. Several 4-foot-thick pumpable cementitious seal designs, which had been previously performance-tested in the LLEM and subsequently approved by MSHA, effectively contained the explosion, thereby sparing the miners working nearby.

Outputs

11 Outputs

Title	Year	Output Type	Strategic Goal
Alternative Methodologies for Evaluating Explosion-resistant Mine Ventilation Seals Sapko-MJ; Weiss-ES; Harteis-SP | In Proceedings of the 30th International Conference of Safety in Mines Research Institutes. Johannesburg, Republic of South Africa: South African Institute of Mining and Metallurgy, 2003 Oct; :615-640	2003	Publication	Mine disasters
Designs for Rapid In-Situ Sealing Sapko-MJ; Weiss-ES; Trackemas-J; Stephan-CR | In: Proceedings of the Annual Meeting of the Society for Mining, Metallurgy, and Exploration, Inc (Feb 2003; Cincinnati, OH). Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :8 pp	2003	Publication	Mine disasters
Evaluation of Explosion-Resistant Seals, Stoppings, and Overcast for Ventilation Control in Underground Coal Mining Weiss-ES; Cashdollar-KL; Sapko-MJ | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centrs for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2003-104, Report of Investigations 9659, 2002	2002	Publication	Mine disasters
Evaluation of New Methods and Facilities to Test Explosion-Resistant Seals Sapko-MJ; Weiss-ES | In: Proceedings of the 29th International Conference of Safety in Mines Research Institutes. Vol. 1. Katowice, Poland: Central Mining Institute, 2001; :157-166	2001	Publication	Mine disasters
Evaluation of Reinforced Cementitious Seals Weiss-ES; Cashdollar-KL; Mutton-IVS; Kohli-DR; Slivensky-WA | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 99-136, Report of Investigations 9647, 1999	1999	Publication	Mine disasters
Evaluation of Water Trap Designs and Alternative Mine Seal Construction Materials Weiss-ES; Slivensky-WA; Schultz-MJ; Stephan-CR | In: Dhar BB, Bhowmick BC, eds. Proceedings of the 27th International Conference of Safety in Mines Research Institutes Vol. 2, New Delhi, India: Oxford & IBH Publishing Co. Pvt. Ltd., 1997; :973-981	1997	Publication	Mine disasters
Methods for Evaluating Explosion Resistant Ventilation Structures Sapko-MJ; Weiss-ES; Harteis-SP | In: Eighth International Mine Ventilation Congress (Brisbane, Australia); :211-219	2005	Publication	Mine disasters
Overview of NIOSH's Mine Seal Research Sapko-MJ; Weiss-ES; Cashdollar-KL; Greninger-NB | In: Proceedings of the 28th International Conference of Safety in Mines Research Institutes (Sinaia, Romania). Vol. I, 1999; :71-85	1999	Publication	Mine disasters
Recent Mine Seal Research Conducted by NIOSH Sapko-MJ; Weiss-ES; Greninger-NB | In: Sealbarr '99 - Proceedings of the Polish-American Seminar on Seals and Barriers as a Means of Protection Against Fires and Explosions in Mines (Katowice, Poland, May 27-28, 1999),1999 May; :39-53	1999	Publication	Mine disasters
Technology News 490 - An Inexpensive Device for Monitoring Explosions in Sealed Areas of Underground Mines NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 490, 2001 Jun :1-2	2001	Publication	Mine disasters
Alternative Methodologies for Evaluating Strength of Mine Seals Workshop NIOSH | Workshop presented to the coal industry, seal manufacturers, MSHA, PA Bureau of Deep Mine Safety, and the United Mine Workers of America (Sept 8, 2004, Pittsburgh, PA; 77 participants)	2004	Workshop, Seminar, or OIB	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Realistic Training for Mine Emergency Responders

Description of Problem

Because of the unique hazards in the underground mine environment, responders to mine emergencies, including miners, fire brigades, and mine rescue teams, need realistic training exercises to ensure their safety and readiness.

Injured miner receiving first aid during rescue team training

Research and Development Activities

In partnership with state agencies, the Mine Safety and Health Administration, and mining companies, realistic underground training exercises were and are being developed, conducted, and evaluated. Since 1998, more than 150 mine rescue, firefighting, and escape simulations have been held at Lake Lynn Lab and at operating coal and metal/nonmetal mines. More than 3,000 miners have participated.

R&D Outputs and Transfer Activities

Miners experienced traveling through smoke-filled entries using directional lifelines, handheld lasers, chemical light sticks, and strobe lights to guide them. Fire brigade members fought actual conveyor belt fires and extinguished diesel fuel tray fires with water lines, chemical powder, and foam. Mine rescue teams explored smoke-filled underground passageways, built stoppings and cribs, rescued "injured" miners, and reestablished ventilation to remove hazardous gases. During the exercises, the participants evaluated various NIOSH-identified and/or developed technologies to enhance their safety and operational effectiveness. These include the patented lighted team link line, extendable wheeled stretcher cart, lifeline pulleys, and emergency communication systems.

Description of Intermediate Outcome

The exercises were highly rated by the participants, agency instructors, and mine safety officials. As a result of the exercises, the participants, including command center personnel, gained a better awareness of the hazards associated with mine emergencies, increased their skill and confidence levels, improved decision-making capabilities, and enhanced the safety and operational effectiveness of mine rescue teams and fire brigades. Rescue team members who had successfully extinguished a conveyor belt fire at Mine 84 (Eighty Four Mining Co.) in Pennsylvania in January 2003 stated that NIOSH training was the best preparation they had received for fighting an actual fire. Several rescue teams, including the six Pennsylvania state-trained teams, have adopted the lifeline pulleys, magnetic mapboards, and chemical light sticks. Consol Energy, Inc., teams used 50 lifeline pulleys and chemical light sticks to help in recovering the Buchanan Mine, which was temporarily sealed because of a fire in 2005.

Outputs

5 Outputs

Title	Year	Output Type	Strategic Goal
An Overview of Technology and Training Simulations for Mine Rescue Teams Conti-RS; Chasko-LL; Cool-JD | Proceedings of the 28th International Conference of Safety in Mines Research Institutes (Jun 7-11, 1999; Sinaia, Romania), Vol. II; :521-538	1999	Publication	Mine disasters
Emerging Technologies: Aiding Responders in Mine Emergences and During the Escape From Smoke-Filled Passageways Conti-RS | Proc Northwest Mining Association 107th Annual Meeting, Exposition and Short Courses (December 3-7, 2001; Spokane, WA); :14 pp	2001	Publication	Mine disasters; Surveillance and training
Lighted Line Conti-RS; Chasko-LL | U.S. Patent #6,742,909	2004	Patent	Mine disasters
Mine Rescue and Response Conti-RS | Proceedings of the 12th International Conference on Coal Research - Coal the Future (Sep 12-15, 2000; Sandton, Republic of South Africa). Symposium Series S26, International Committee for Coal Research, Washington, DC; :127-136	2000	Publication	Mine disasters
Responders To Underground Mine Fires Conti-RS | Proceedings of the 32nd Annual Conference of the Institute on Mining Health, Safety and Research (Aug 5-7, 2001; Salt Lake City, UT), University of Utah; :111-121	2001	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Revised Standards for National Fire Protection Association (2002-2004)

Description of Problem

In January 2002, the National Fire Protection Association (NFPA) began an effort to completely rewrite the outdated mining fire protection standards to bring them up to the state of the art in fire protection. The standards were also to include new sections to cover surface mining equipment, crushing operations, and coal loadouts. This was the first major rewrite since the standards had been adopted in 1981.

A fire suppression experiment in a diesel fuel storage area

Research and Development Activities

NIOSH played a key role in developing the 2004 revised mining standards: NFPA 120 - Standard for Fire Prevention and Control in Underground Coal Mines, and NFPA 122 - Standard for Fire Prevention and Control in Metal and Nonmetal Mines. NIOSH experts were invited to serve on the NFPA Technical Committee on Mining Facilities. The committee is composed of representatives from the mining industry, manufacturers of mining equipment, insurance and risk management firms, the fire protection industry, and consultants to the mining industry. During the rewrite, four separate standards were combined into two (120 and 122). These four standards were: NFPA 120 - Standard for Coal Preparation Plants, NFPA 121 - Standard on Fire Protection for Self-Propelled and Mobile Surface Mining Equipment, NFPA 122 - Standard for Fire Prevention and Control in Underground Metal and Nonmetal Mines, and NFPA 123 - Standard for Fire Prevention and Control in Underground Bituminous Coal Mines.

R&D Outputs and Transfer Activities

Two standards, NFPA 120 and 122, were completed and published in August 2004. The diverse membership of the technical committee ensures that the research results are disseminated to a wide spectrum of industries. NIOSH research is referenced extensively in the new standards, particularly in sections on detecting and suppressing mine fires, surface mobile equipment fires, and mine fire statistics.

Description of Intermediate Outcome

NFPA's mission is to reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating scientifically based consensus codes and standards, research, training, and education. The NFPA serves as the world's leading advocate of fire prevention and is an authoritative source on public safety. The NFPA's 300 codes and standards influence every building, process, service, design, and installation in the United States, as well as many of those used in other countries. NFPA's focus on true consensus has helped the association's code development process earn accreditation from the American National Standards Institute (ANSI).

Outputs

2 Outputs

Title	Year	Output Type	Strategic Goal
NFPA 120 - Standard for Fire Prevention and Control in Coal Mines National Fire Protection Association | Quincy, MA: National Fire Protection Association	2004	Standards	Mine disasters
NFPA 122 - Standard for Fire Prevention and Control in Metal/Nonmetal Mining and Metal Mineral Processing Facilities National Fire Protection Association | Quincy, MA: National Fire Protection Association	2004	Standards	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Transfer of Explosions and Fire Expertise and Test Procedures to Industry (1992-2005)

Description of Problem

Knowledge of material flammability and explosibility characteristics is essential to industries that manufacture, process, generate, or use combustible dusts and gases. These industries include mining, metals, chemicals, plastics, agriculture, and electric power generation. Most important to their mission is the need for reliable, peer-reviewed information, guidelines, and standards to help protect workers from accidental fires or explosions.

Research and Development Activities

Fire and explosion safety expertise, test equipment, and test procedures developed at the NIOSH Pittsburgh Research Laboratory (PRL) for the mining industry have been transferred to other industries. This included the development of consensus standard test methods through the American Society for Testing and Materials (ASTM) International Committee E27 on the Hazard Potential of Chemicals. The four test methods approved are: E1491 for the Minimum Autoignition Temperature of Dust Clouds (1992), E1515 for the Minimum Explosible Concentration of Combustible Dusts (1993, revised in 2003), E2021 for the Hot-surface Ignition Temperature of Dust Layers (2001), and E2079 for the Limiting Oxygen Concentration in Gases and Vapors (2001). Additional test methods for limiting oxygen concentrations of dust clouds and flammability limits of gases using a pressure criterion are currently being considered by the ASTM E27 committee.

R&D Outputs and Transfer Activities

These consensus standard test methods have been published by ASTM International and are now being used by the Occupational Safety and Health Administration (OSHA), private testing labs, and various industrial labs to evaluate the ignitability and explosibility of dusts and gases. Information on the measurement of gas and dust explosibility characteristics has also been widely distributed to various safety personnel in industry through various journal and book publications.

Description of Intermediate Outcome

Based on an ASTM survey in 2004, the four test methods are used more than 400 times per year by various industries to assess their explosion hazards. The data from these tests are used to develop protective measures in industry to prevent gas and dust explosions and fires. Copies of the summary explosion publications were requested by members of the Chemical Safety and Hazard Investigation Board to assist in their investigations of recent industrial dust explosions. The summary dust explosion publications provide help and guidance to the practicing safety engineer regarding the important variables in dust explosibility, particularly the importance of particle size.

Outputs

6 Outputs

Title	Year	Output Type	Strategic Goal
Flammability Limit Measurements for Dusts in 20-L and 1-m3 Vessels Going-JE; Chatrathi-K; Cashdollar-KL | Journal of Loss Prevention in the Process Ind, 13(3), 2003 May; :209-219	2000	Publication	Mine disasters
Flammability of Methane, Propane, and Hydrogen Gases Cashdollar-KL; Zlochower-IA; Green-GM; Thomas-RA; Hertzberg-M | Journal of Loss Prevention in the Process Industries, 13(3-5), 2000 May; :327-340	2000	Publication	Mine disasters
Overview of Dust Explosibility Characteristics Cashdollar-KL | J Loss Prevention in the Process Industries, 2000 May; 13(3-5); :183-199	2000	Publication	Mine disasters
Predicting Flammability of Gas Mixtures Containing Volatile Organic Compounds Liekhus-K; Zlochower-IA; Cashdollar-KL; Djordjevic-S; Loehr-C | J. Loss Prev. Process Industries, v 13; :377 384	2000	Publication	Mine disasters
Properties of Combustible Dusts (Safety Characteristics) Hensel-W; Cashdollar-KL | Chapter In: Hattwig M and Steen H, eds. Handbook of Explosion Prevention and Protection (English translation of Handbuch des Explosionsschutzes, originally published in German, April 2000), Wiley-VCH, 2004; :379-417	2004	Publication	Mine disasters
The Role of ASTM E27 Methods in Hazard Assessment: Part II - Flammability and Ignitability Britton-LG; Cashdollar-KL; Fenlon-W; Frurip-D; Going-J; Harrison-BK; Niemeier-J; Ural-EA | Process Saf Prog 24(1), 2005; :12-28	2005	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Utilization of Large-Diameter Propeller Fans

Description of Problem

Most operators of large-opening mines have relied on inadequate mine ventilation methods, such as natural ventilation or mine ventilation fans typically designed for coal mines. It became evident that the ventilation practices and fan selections were inadequate to reduce worker exposure to airborne contaminants.

Installation of large diameter propeller fan in large opening mine

Research and Development Activities

NIOSH researchers conducted an extensive review of available ventilation fans and their potential suitability for large-opening mines. It was determined that large-diameter propeller fans would be best suited for these mines. The researchers conducted a mine case study where two large-diameter propeller fans were selected, installed, and evaluated in an operating large-opening stone mine. The study demonstrated that propeller fans could effectively increase ventilation airflow quantities. Propeller fans are more efficient than axial vane fans in large-opening mine conditions. They create less noise, require less capital investment, and have lower operating costs compared to axial vane fans previously used in these mining operations.

R&D Outputs and Transfer Activities

The successful use of propeller fans was described during presentations at three annual NIOSH Safety Seminars for Underground Stone Mines and at two mining symposia. The concept has been demonstrated in a case study at a commercial mine, and several on-site technology transfer sessions have been presented to other mine operators.

Description of Intermediate Outcome

Propeller fans have become more common in underground large-opening mines. Currently, there are at least seven mining operations that use propeller fans as main mine fans. Spendrup Fan Co. started manufacturing main mine propeller fans. Both Hartzell Fan Co. and Spendrup Fan Co. started manufacturing portable diesel-powered propeller fans.

Outputs

5 Outputs

Title	Year	Output Type	Strategic Goal
NIOSH Ventilation Research Addressing Diesel Emissions and Other Air Quality Issues in Nonmetal Mines Grau-RH III; Robertson-SB; Mucho-T; Garcia-F, Smith-AC | Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., Transactions 2004, Vol. 316; :149-158	2004	Publication	Mine disasters
NIOSH Ventilation Research Addressing Diesel Emissions and Other Air Quality Issues in Nonmetal Mines Grau-RH; Robertson-SB; Mucho-TP; Garcia-F; Smith-AC | 2002 SME Annual Meeting (Phoenix, Arizona; Feb 25-27, 2002). SME preprint 02-187. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :1-7	2002	Publication	Mine disasters; Respiratory diseases
Practical Techniques to Improve the Air Quality in Underground Stone Mines Grau-RH; Mucho-TP; Robertson-SB; Smith-AC; Garcia-SF | In: De Souze E, ed. Mine Ventilation: Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Kingston, Ontario, Canada) Lisse, Netherlands: A. A. Balkema, 2002 Oct; :123-129	2002	Publication	Mine disasters; Respiratory diseases
Raising the Bar of Ventilation for Large-Opening Stone Mines Grau-RH; Robertson-SB; Krog-RB; Chekan-GJ; Mucho-TP | In: Ganguli R, Bandopadhyay S, eds. Mine Ventilation: Proc 10th U.S./North American Mine Ventilation Symposium (Anchorage, Alaska, May 16-19 2004). Leiden, Netherlands: A. A. Balkema, 2004 May; :349-355	2004	Publication	Mine disasters; Respiratory diseases
Technology News 499 - Using Propeller Fans to Improve Ventilation in Large-Entry Stone Mines Grau-RH III; Robertson-SB | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 499, 2002 Dec :1-2	2002	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Ventilating Large-Opening Stone Mines using Novel Ventilation Techniques

Description of Problem

NIOSH researchers investigated ventilation practices at several large-opening mines and determined that a more efficient ventilation design was needed to establish a sufficient and stable airflow to the working face of the mine in order to reduce airborne contaminants to acceptable levels.

Propeller fan blowing into a new mine using split-mine ventilation

Research and Development Activities

Effective ventilation planning in conjunction with mine design is essential for creating an efficient ventilation system for the life of the mine. Prior to this research, the common mining and ventilation practice in large-opening mines gave little regard to the integration of ventilation into the mining plan. These mines relied on natural ventilation and less-than-optimal use of freestanding auxiliary fans. This resulted in inadequate ventilation at the face of the mine.

NIOSH researchers developed two improved ventilation concepts - perimeter ventilation and split ventilation. Both concepts use a stopping line to separate the intake air from the return air in order to create a larger pressure drop between the two airstreams. Ventilation planning becomes an integral part of the mine design process by using either concept. Perimeter ventilation has the advantage that it can be applied to older, mature mines that have an extensive network of large openings. It requires a minimum number of stoppings to be built to properly course the air to the active mine workings. Split ventilation is better suited for newer or smaller mines. In these mines, the stopping line is built concurrent with mine development by leaving long pillars.

R&D Outputs and Transfer Activities

Results of this research have been presented at several industry seminars and conferences, as well as during site visits to the engineering staffs at two partnering mining operations. Several mine operators have visited the mine site of the successful application of the perimeter-ventilation method to learn firsthand how it works. The concepts to improve large-opening mine ventilation have also been described in depth to the Mine Safety and Health Administration's (MSHA) Technical Support group during several meetings.

Description of Intermediate Outcome

Hanson Aggregates (Latrobe and Whitney Mines) is using perimeter ventilation, and Coolspring Stone Supply, Inc., (Coolspring Mine) is using split ventilation. The use of the NIOSH-developed ventilation concepts by these mine operators is a long-term commitment and verifies acceptance by the industry.

MSHA is providing information to stone mine operators about this research to help them improve their ventilation systems.

Outputs

7 Outputs

Title	Year	Output Type	Strategic Goal
Evaluating Ventilating Air Movement in Underground Limestone Mines by Monitoring Respirable Dust Generated from Production Shots Chekan-GJ; Colinet-JF; Grau-RH III | In: Ganguli R, Bandopadhyay S, eds. Mine ventilation: Proceedings of the 10th U.S./North American Mine Ventilation Sympsoim (Anchorage, AK, May 16-19, 2004). Leiden, Netherlands: Balkema,2004; :221-232	2004	Publication	Mine disasters; Respiratory diseases
NIOSH Ventilation Research Addressing Diesel Emissions and Other Air Quality Issues in Nonmetal Mines Grau-RH III; Robertson-SB; Mucho-T; Garcia-F, Smith-AC | Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., Transactions 2004, Vol. 316; :149-158	2004	Publication	Mine disasters
NIOSH Ventilation Research Addressing Diesel Emissions and Other Air Quality Issues in Nonmetal Mines Grau-RH; Robertson-SB; Mucho-TP; Garcia-F; Smith-AC | 2002 SME Annual Meeting (Phoenix, Arizona; Feb 25-27, 2002). SME preprint 02-187. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :1-7	2002	Publication	Mine disasters; Respiratory diseases
Practical Techniques to Improve the Air Quality in Underground Stone Mines Grau-RH; Mucho-TP; Robertson-SB; Smith-AC; Garcia-SF | In: De Souze E, ed. Mine Ventilation: Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Kingston, Ontario, Canada) Lisse, Netherlands: A. A. Balkema, 2002 Oct; :123-129	2002	Publication	Mine disasters; Respiratory diseases
Raising the Bar of Ventilation for Large-Opening Stone Mines Grau-RH; Robertson-SB; Krog-RB; Chekan-GJ; Mucho-TP | In: Ganguli R, Bandopadhyay S, eds. Mine Ventilation: Proc 10th U.S./North American Mine Ventilation Symposium (Anchorage, Alaska, May 16-19 2004). Leiden, Netherlands: A. A. Balkema, 2004 May; :349-355	2004	Publication	Mine disasters; Respiratory diseases
Technology News 500 - Using In-Place Stone Stoppings to Direct Air in Underground Stone Mines NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 500, 2002 Dec :1-2	2002	Publication	Mine disasters; Respiratory diseases
Ventilation Planning Layouts for Large Opening Mines Krog-RB; Grau-RH; Mucho-TP; Robertson-SB | 2004 SME Annual Meeting, Feb 23-25, Denver, Colorado, preprint 04-187. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004 Feb; :1-9	2004	Publication	Mine disasters; Respiratory diseases

Strategic Program Outcome for Ground Control

Reducing Fatalities and Injuries Due to Ground Failures

Ground falls in U.S. underground mines (coal and nonmetal) caused more than 50,000 deaths or about half of all mining fatalities during the 20th century. Over the past 10 years, there have been significant improvements in ground control safety. Figure 1 shows that the roof fall fatality rate in U.S. underground mines has averaged 0.001 per 200,000 during the past 3 years, down 69% from its average during 1980-1995. In addition, the rock fall injury rate has fallen in each of the last 4 years to a level about 25% below its former plateau.

NIOSH has contributed to this historic improvement through its customer-focused, goal-oriented ground control research program. Important NIOSH research products that have been successfully transferred to and implemented by the mining community during the past decade include:

- The Support Technology Optimization Program (STOP) and Analysis of Longwall Pillar Stability (ALPS) programs, which together have contributed to a virtual elimination of tailgate blockages.
- The underground stone ground control safety initiative. This initiative has increased awareness about rock fall hazards and helped to greatly reduce fatalities in stone mines.
- Guidelines for coal pillar recovery and widespread use of mobile roof supports. These have helped make pillar recovery much safer.
- Guidelines for designing deep-cover mines to prevent coal bumps (violent failures of highly stressed coal). These guidelines have contributed to 7 consecutive years with no fatalities due to coal bumps.
- New standing roof supports. These have helped reduce the number of roof falls and the number of injuries to miners while installing roof support.
- A research and educational campaign aimed at increasing awareness about rock fall injuries and the use of surface controls in coal mines. This has helped reduce rock fall injury rates.
- Mine design technologies such as the Coal Mine Roof Rating (CMRR) and Analysis of Horizontal Stress in Mines (AHSM), and guidelines for preventing massive pillar collapses. These have helped provide more stable mining environments.

More details on each of these accomplishments and impacts can be found in the "Intermediate Outcome" write-ups.

An essential part of the success of the NIOSH ground control program has been an effective technology transfer effort. The centerpiece has been the suite of ground control software packages that has been developed from the research. There are now eight NIOSH programs. These address nearly every aspect of ground control planning for coal mines. This includes geologic characterization, mine layout, pillar design, and support selection. These products are used throughout the mining community. They are among the most requested and downloaded products from the NIOSH Mining Website. Other technology transfer efforts include:

- Hands-on ground control software computer training workshops held in six U.S. coalfield locations. These were attended by nearly 300 mine planners.
- Annual safety seminars for underground stone mines. These are attended by more than 150 professionals in the stone industry each year.
- Open industry briefings on coal mine roof support. These were held in eight U.S. coalfield locations and reached 750 mining industry personnel.
- Ground control short courses conducted for Massey Energy and Peabody Energy.
- Ground control training provided in eight sessions for all 400 coal mine inspectors from the Mine Safety and Health Administration (MSHA) at the agency´s request.
- An annual response to an average of 200 technical requests and 40 visits at coal and nonmetal mine sites.

Another important component of our technology transfer program is the MSHA-NIOSH partnership in the Preventative Roof-Rib Outreach Program (PROP). PROP has sponsored nearly a dozen full-day or half-day seminars in nearly every MSHA coal mining district. These seminars are tailored for the specific needs of each district. Attendance at these seminars is usually 50 to 100. NIOSH provides about half of the speakers. In addition, PROP has sponsored 2-day seminars at MSHA´s National Mine Health and Safety Academy in each of the last 5 years. These were attended by about 150 miners each year.

NIOSH has developed a particularly close relationship with the MSHA Technical Support group at Bruceton, PA. Our collaborations with them facilitate quick results and implementation by the MSHA districts. Partnerships with mine roof support manufacturers have greatly enhanced the effectiveness of the NIOSH mine roof simulator (MRS). The impartiality of safety testing in the MRS is accepted across the mining community. Thus, NIOSH has been able to help in the rapid commercialization of more than 40 new roof support technologies over the past 5 years.

International collaboration is another measure of the caliber and impact of the NIOSH ground control program. During the past 8 years, six major funded research projects in Australia, Canada, the European Union, and the Republic of South Africa were based on NIOSH research. These focused on the STOP, ALPS, Analysis of Retreat Mining Pillar Stability (ARMPS), and CMRR software packages.

A new initiative is aimed at developing a set of engineering design guidelines to minimize unplanned roof failures in underground stone mines. Another software package will help coal mine planners minimize hazards when using multiple-seam mining techniques. Recent advances have coupled microseismic monitoring of rock failure events to measurements of mine roof movements. This has resulted in a sensor-based roof fall warning technology for identifying potentially hazardous areas. Standing support improvements and a better understanding of rock mass behaviors will provide opportunities for reducing the threat posed by massive roof falls to underground workers.

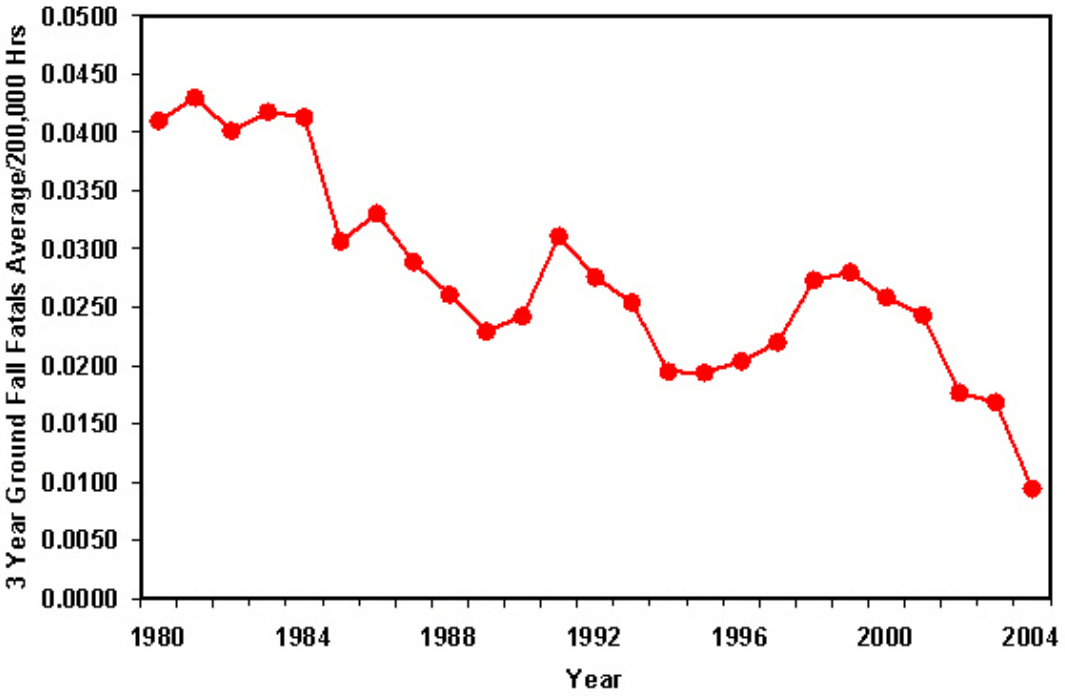


Figure 1. Ground fall fatality rate in underground mines (3-year moving average).

Rock burst control for hard-rock mines has been part of the ground control research program for more than 30 years. Great progress has been made in alleviating the rock burst problem in U.S. deep-metal mines. Seismic monitoring, in conjunction with rock mass behavior measurements and numerical modeling, has led to the development of safer mining methods and layouts.

NIOSH has also provided solutions to reduce ground fall hazards in Nevada underground mines. From 1999 to 2005, the mine design curves and applicable nomograms resulting from this research were transferred to the mining industry through 11 technical papers and 9 presentations.

Intermediate Outcomes

- Characterizing Coal Measure Rocks Using the Coal Mine Roof Rating System
- Control of Horizontal Stress in Mining to Reduce Injuries and Fatalities
- Design Guidelines for Safe Highwall Mining Systems
- Guidelines for Coal Pillar Recovery
- Mitigating Ground Fall Hazards in Underground Stone Mines
- Mobile Roof Supports for Retreat Room-and-Pillar Mines
- NIOSH Support Technology Optimization Program (STOP) Design Software
- Preventing Longwall Tailgate Blockages
- Preventing Massive Coal Pillar Collapses
- Reducing Rock Fall Injuries to Coal Miners
- Rock Burst Control in Deep Metal Mines

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Characterizing Coal Measure Rocks Using the Coal Mine Roof Rating System

Description of Problem

Roof falls continue to be one of the greatest hazards faced by underground coal miners. They can damage equipment, disrupt ventilation, and block critical emergency escape routes. One reason that roof falls have been so difficult to eradicate is that the structural integrity of a coal mine´s roof is greatly affected by natural weaknesses, including bedding planes, fractures, and small faults. The engineering properties of rock cannot be quantified solely by lab tests because the strength of a small specimen is representative only of that sample and does not take into account the imperfections caused by discontinuities.

Researchers examining a roof fall to calculate roof strength using CMRR observational techniques

Research and Development Activities

NIOSH developed the Coal Mine Roof Rating (CMRR) system 10 years ago to fill the gap between geologic characterization and engineering design. It combines many years of geologic studies in underground coal mines with worldwide experience with rock mass classification systems. New CMRR procedures for borehole drill core, together with a software package, were developed in 2000 and made it possible to routinely collect CMRR data during geologic exploration. Worldwide experience has shown that the CMRR is a reliable, meaningful, and repeatable measure of mine roof quality.

R&D Outputs and Transfer Activities

NIOSH transferred the new CMRR software package to the mining community through a series of open industry briefings that included hands-on computer training sessions. Presentations on the CMRR have also been given at conferences in the United States and Australia. In addition, NIOSH has responded to requests for assistance in using the CMRR from many mining companies and geologic consultants, both domestic and abroad.

Description of Intermediate Outcome

NIOSH developed a wide variety of ground control design tools based on the CMRR. These tools address a broad range of issues, including longwall pillar design, roof support selection, feasibility studies, extended-cut evaluation, and others. As a result, the CMRR is becoming the accepted standard for geotechnical characterization of mine roof and is often referred to in the technical literature. Peabody Energy, the largest U.S. coal producer, routinely uses the CMRR

in all of its exploration and mine planning activities. The CMRR has also become truly international. It is involved in mine designs and in research projects funded by the Safety in Mines Research Advisory Committee (South Africa), the Canada Centre for Mineral and Energy Technology, and the Australian Coal Association Research Program.

Outputs

13 Outputs

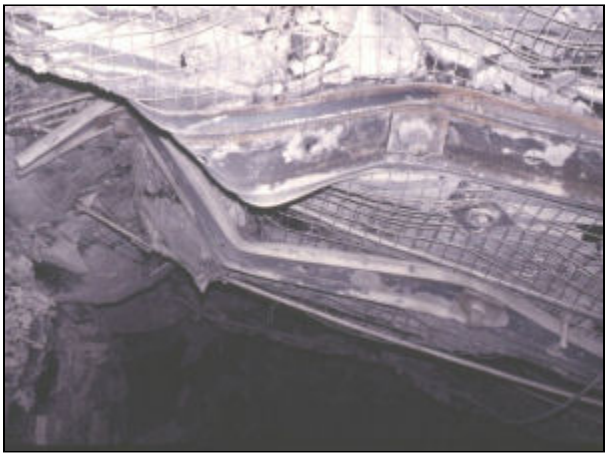
Title	Year	Output Type	Strategic Goal
Application of the Coal Mine Roof Rating (CMRR) to Extended Cuts Mark-C | Min Eng 51(4); :52-56	1999	Publication	Ground control
Comparison of Ground Conditions and Ground Control Practices in the United States and Australia Marc-C | Min Eng 51(4):52-56	1998	Publication	Ground control
Geologic Hazards and Roof Stability in Coal Mines Molinda-GM | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2003-152, IC 9466; 1-33	2003	Publication	Ground control
Ground Control in South African Coal Mines: A U.S. Perspective Mark-C | In: Proceedings of the 18th International Conference on Ground Control in Mining, Peng SS, Mark C, eds., Morgantown, WV: West Virginia University, 1999; :186-193	1999	Publication	Ground control
New Coal Mine Roof Rating (CMRR) Improves Safety in U.S. Underground Mines Molinda-GM; Mark-C | In: Proceedings of the 27th International Conference of Safety in Mines Research Institutes, Dhar BB, Bhowmick BC, eds., Vol. 2. New Delhi, India: Oxford & IBH Publishing Co. Pvt. Ltd., 1997; :1001-1011	1997	Publication	Ground control
New Developments with the Coal Mine Roof Rating Mark-C; Molinda-GM; Barton-TM | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :294-301	2002	Publication	Ground control
Spatial Trends in Rock Strength - Can They Be Determined From Coreholes? Mark-C; McWilliams-LJ; Pappas-DM; Rusnak-JA | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, pp. 177-182	2004	Publication	Ground control
Standardization of Geological and Geomechanical Assessment at Underground Coal Mines in Canada Forgeron-S; Mark-C; Forrester-DJ | CIM Bulletin 2001 Jul; :83-90	2001	Publication	Ground control
Technology News 505 - NIOSH Releases New Coal Mine Roof Rating Software NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 505, April 2003; :1-2	2003	Publication	Ground control
The Coal Mine Roof Rating in Mining Engineering Practice Mark-C; Molinda-GM | In: Aziz N, Kininmonth B, eds. Proceedings of the Fourth Underground Coal Operators' Conference. Carlton, Australia: Australian Institute of Mining and Metallurgy	2003	Publication	Ground control
Using the Coal Mine Roof Rating (CMRR) to Assess Roof Stability in U.S. Coal Mines Molinda-GM; Mark-C; Debasis-D | Journal of Mines, Metals, and Fuels (India) Aug-Sep 2001; :314-321	2001	Publication	Ground control
Using the Point Load Test to Determine the Uniaxial Compressive Strength of Coal Measure Rock Rusnak J; Mark C | In: Peng SS, Mark C, eds. Proceedings of the 19th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, pp. 362-371	2000	Publication	Ground control
Coal Mine Roof Rating (CMRR) NIOSH | NIOSH 2004 Dec; :Software	2004	Software	Ground control

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Control of Horizontal Stress in Mining to Reduce Injuries and Fatalities

Description of Problem

Horizontal stresses have contributed to thousands of ground falls in underground mines throughout the Eastern United States. Fifteen years ago, however, the very existence of horizontal stress was questioned by many within the mining community. NIOSH research proved that horizontal stresses are directly linked to plate tectonics and continental drift and that they are the most significant ground stress (exceeding the gravity load) in most underground mines.



Horizontal cutter roof created by high horizontal mine stresses

Research and Development Activities

NIOSH has built upon its fundamental scientific breakthrough to develop a variety of stress control technologies. For coal mines, NIOSH products include:

- Guidelines for mine layout to minimize stress (1994)
- Methods for orientating and sequencing of longwall panels to prevent extreme headgate stress concentrations (1997)
- An innovative advance-and-relieve mine design for pillar recovery (1999)
- Analysis of Horizontal Stress in Mines (AHSEM), a computer program that aids mine planners in designing safer mines (2001)

NIOSH research has also aided underground stone mines that suffer from horizontal stress. NIOSH has measured horizontal stress levels that were as great as 10 times gravity overburden loads in stiff limestone roof. NIOSH also developed a novel stress control mine design that has greatly reduced the number of roof falls at several underground limestone mines.

R&D Outputs and Transfer Activities

All of these technologies have been transferred to the mining community through an aggressive program of publications, workshops, and open industry briefings:

- An Information Circular (IC) entitled "New Technology for Longwall Ground Control" and associated open industry briefings in several U.S. coalfields (1994)
- A seminal paper, published in Mining Engineering magazine, describing horizontal stress concentrations in longwall headgates and methods to prevent them

- Presentations at NIOSH's annual Safety Seminar for Underground Stone Mines
- A series of hands-on computer training workshops on the AHSEM program
- Numerous presentations at conferences, open industry briefings, company ground control short courses, Preventative Roof-Rib Outreach Program (PROP) seminars, and other venues

Description of Intermediate Outcome

Proper orientation and sequencing has largely eliminated the major headgate failures that were quite common in longwall mines before 1998. Thanks in large part to the educational effort undertaken by NIOSH, today's mine planners understand horizontal stress and consider it during mine layout. The NIOSH-developed control technologies are used widely throughout the mining community and are often referenced.

Outputs

15 Outputs

Title	Year	Output Type	Strategic Goal
Advance and Relieve Mining: A Method to Mitigate the Effects of High Horizontal Stress on the Mine Roof Dolinar-DR; Mucho-TP; Oyler-DC; Pablic-J | SME, Inc., Preprint 01-113, SME Annual Meeting, Denver, Colorado - February 26-28, 2001; :1-12	2001	Publication	Ground control
Controlling Roof Beam Failures From High Horizontal Stresses in Underground Stone Mines Iannacchione-AT; Dolinar-DR; Prosser-LJ; Marshall-TE; Oyler-DC; Compton-CS | In: Proceedings of the 17th International Conference on Ground Control in Mining, Peng SS, ed., Morgantown, WV: University of West Virginia, 1998 Aug 4-6, 1998 Aug; :102-112.	1998	Publication	Ground control
Controlling Roof Beam Failures From High Horizontal Stresses in Underground Stone Mines Iannacchione AT, Dolinar DR, Prosser LJ Jr., Marshall TE, Oyler DC, Compton CS | In: Aziz NI, Indraratna B, eds. Proceedings of the International Conference on Geomechanics/Ground Control in Mining and Underground Construction, Wollongong, New South Wales, Australia: University of Wollongong, Vol. 2, 1998; :525-541	1998	Publication	Ground control
Development and Use of a High-pressure Packer for Measuring Horizontal Stress Using the Hydraulic Fracturing Method Oyler-DC | In: Elsworth D, Tinucci JP, Heasley KA, eds. Rock Mechanics in the National Interest. Vol. I. Lisse, Netherlands: Swets & Zeitlinger; :227-234	2001	Publication	Ground control
Development of a Fiber Optic Stress Sensor Heasley-KA; Dubaniewicz-TH Jr.; DiMartino-MD | In: Proceedings of the 36th U.S. Rock Mechanics Symposium, Hudson JA, ed., New York, NY: Columbia University, Paper No. 066, 1997	1997	Publication	Ground control
Focus on Ground Control: Horizontal Stress Mark-C | Coal Age 106(3):47-51	2001	Publication	Ground control
High Stress Mining Under Shallow Overburden in Underground U.S. Stone Mines Iannacchione-AT; Dolinar-DR; Mucho-TP | In: Proceedings of the First International Seminar on Deep and High-Stress Mining. Nedlands, Australia: Australian Centre for Geomechanics, section 32, 2002 Nov; :1-11	2002	Publication	Ground control
Horizontal Stress And Longwall Headgate Ground Control Mark-C; Mucho-TP; Dolinar-D | SME preprint 97-187, 1997	1997	Publication	Ground control
Horizontal Stress and Longwall Headgate Ground Control Mark-C; Mucho-TP; Dolinar-D | Min Eng 1998 Jan :61-68	1998	Publication	Ground control
Rock Mechanics Study of Lateral Destressing for the Advance-and-Relieve Mining Method Maleki-H; Dolinar-DR; Dubbert-J | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University; :105-113	2003	Publication	Ground control
Safer Mine Layouts for Underground Stone Mines Subjected to Excessive Levels of Horizontal Stress Iannacchione-AT; Marshall-TE; Burke-L; Melville-R; Litsenberger-J | Mining Engineering, 55(4), 2003 Apr; :25-31	2003	Publication	Ground control

Title	Year	Output Type	Strategic Goal
The Advance-and-Relieve Mining Method: a Horizontal Stress Control Technique Chase-FE; Mark-C; Mucho-TP; Campbell-PL | In: Proceedings of the 18th International Conference on Ground Control in Mining, Peng SS, Mark C, eds., SMorgantown, WV: West Virginia University, 1999; :300-308	1999	Publication	Ground control
Utilizing the 'Advance and Relieve' Method to Reduce Horizontal Stress Affects on the Mine Roof, A Case Study Dolinar-DR; Mucho-TP; Oyler-DC; Pablic-J | In: Proceedings of the 19th International Conference on Ground Control in Mining, Peng SS, Mark C, eds., Morgantown, WV: West Virginia University, 2000 Jan; :137-148	2000	Publication	Ground control
Variation of Horizontal Stresses and Strains in Mines in Bedded Deposits in the Eastern and Midwestern United States Dolinar-DR | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University; :178-185	2003	Publication	Ground control
Analysis of Horizontal Stress Effects in Mining (AHSM) NIOSH | NIOSH, 2004 Sep, :software	2004	Software	Ground control

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Design Guidelines for Safe Highwall Mining Systems

Description of Problem

The use of highwall mining systems has increased substantially in open-pit coal mines where overburden depth exceeds economical recovery. Highwall stability is a major concern during highwall mining. The Mine Safety and Health Administration requires highwall miner operators to follow ground control plans that specify the web and barrier pillar sizes necessary to prevent a pillar collapse that would threaten highwall stability. Other safety concerns arise when a highwall miner is trapped underground and it becomes necessary to tunnel in to retrieve it.

Highwall mining system extracting a 13 ft thick seam in Wyoming

Research and Development Activities

NIOSH has developed a number of design tools that are relevant to improving ground control during highwall mining operations. The Analysis of Retreat Mining Pillar Stability (ARMPS) computer program is considered particularly useful. It uses the Mark-Bieniawski formula to estimate the strength of long strip pillars. The NIOSH guidelines for preventing massive pillar collapses and the Coal Mine Roof Rating (CMRR) are also applicable to highwall mining. Most recently, NIOSH has developed simple design charts for selecting web and barrier pillar widths, together with guidelines for highwall mining in areas containing old auger holes or two seams in close proximity.

R&D Outputs and Transfer Activities

NIOSH has transferred the ARMPS program to the general mining community through open industry briefings, publications, and computer training workshops. A short course specifically devoted to highwall mining ground control was held for Massey Energy, the largest single user of highwall mining equipment, in 2004. A series of three professional papers on the topic was recently published. Perhaps most importantly, over the past decade, NIOSH ground control experts have responded to more than 50 requests for information about using ARMPS and other NIOSH products to develop safe highwall mining designs.

Description of Intermediate Outcome

A recent survey showed that several MSHA-approved ground control plans for highwall mining specifically mention the ARMPS program. In fact, as evidenced through discussions and training sessions held at open industry briefings, Massey Energy, Fola Coal, and several leading highwall mining consultants routinely use ARMPS or the new design charts for their highwall mining designs.

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
Analysis of Practical Ground Control Issues in Highwall Mining Zipf Jr-RK; Bhatt-SK | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV, August 3-5, 2004: West Virginia University, 2004 Aug; :210-219	2004	Publication	Ground control
Ground Control Design for Highwall Mining Zipf-RK | 2005 SME Annual Meeting, February 28 - March 2, Salt Lake City, Utah, SME preprint 05-82. Littleton, CO, Society for Mining, Metallurgy, and Exploration, Inc., 2005 Feb; :1-7	2005	Publication	Ground control
Analysis of Retreat Mining Pillar Stability (ARMPS) NIOSH | NIOSH, 2003 Aug, :software	2003	Software	Ground control
Coal Mine Roof Rating (CMRR) NIOSH | NIOSH 2004 Dec; :Software	2004	Software	Ground control

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Guidelines for Coal Pillar Recovery

Description of Problem

When coal is first mined, large pillars of coal are left to support the rock between the mine and the surface. When these pillars are later recovered, the ground collapses. Nationally, coal pillar recovery accounts for just 10% of coal mined underground, but it is associated with more than 30% of mine roof fall fatalities.

Retreat mining pillar line roof fall fatality site, Mingo County, West Virginia

Research and Development Activities

NIOSH has been conducting research to reduce the ground fall hazard during coal pillar recovery since the early 1990s. Significant research products include:

- The Analysis of Retreat Mining Pillar Stability (ARMPS) computer program (1994-1997)
- Advocacy of the use of mobile roof supports for temporary roof support (1994-present)
- Guidelines for coal pillar and panel design to prevent massive pillar collapses (1993-1997)
- Guidelines for panel and barrier pillars for pillar recovery under deep cover (2002)
- Guidelines for sizing the final stump to prevent unplanned roof collapse (2001)
- Guidelines for cut sequencing and roof bolting, and identification of other risk factors for pillar recovery, such as old works, multiple-seam mining, and wide roof spans (2002)

R&D Outputs and Transfer Activities

NIOSH has transferred these results through:

- Distribution of more than 1,000 copies of the ARMPS computer program
- A NIOSH Information Circular entitled "New Technology for Ground Control in Retreat Mining." This publication was used in conjunction with an open industry briefing held throughout the U.S. coalfields and attended by more than 300
- Industry short courses for Arch Coal, Massey Energy, and Peabody Energy (100 attendees)
- Joint MSHA-NIOSH Preventative Roof-Rib Outreach Program (PROP) seminars held in MSHA districts and attended by at least 500
- Numerous conference papers and presentations

Description of Intermediate Outcome

Following a series of meetings with MSHA District 4, the West Virginia Office of Miners' Safety, Health, and Training, and the West Virginia Board of Coal Mine Health and Safety, many of the guidelines included in the checklist were incorporated into the roof control plans of nearly 100 mines in southern West Virginia. Others have been implemented in the mining plans of several large mining companies (for example, Massey Energy does not extract the pushout, or remnant pillar). In the 3 years since the guidelines were implemented in District 4, there has been just one fatality associated with coal pillar recovery. This compares with an average of one per year during the prior 5 years. The research has also contributed to significant changes in the way pillar recovery is practiced throughout the United States. Today, more than one-half of all pillars are recovered using mobile roof supports. Fewer and fewer roof control plans allow extraction of the final stump. Mine operators, MSHA, and state regulators are more aware of the risk factors and often specify extra support in pillar recovery sections. Although it is still early to be certain, there is every reason to believe that the national fatality rate for coal pillar recovery will decrease in the future.

Outputs

10 Outputs

Title	Year	Output Type	Strategic Goal
A Statistical Overview of Retreat Mining of Coal Pillars in the United States Mark-C; McCall-FE; Pappas-DM | In: Peng SS, ed., Proceedings of the 16th International Conference on Ground Control in Mining, Morgantown, WV: West Virginia University; 204-210	1997	Publication	Ground control; Surveillance and training
Deep Cover Pillar Extraction in the U.S. Coalfields Chase-FE; Mark-C; Heasley-KA | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :68-80	2002	Publication	Ground control
Evaluation of Pillar Recovery in Southern West Virginia Mark-C; Karabin-G; Zelanko-JC; Hoch-MT; Chase-F | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; : 81-89	2002	Publication	Ground control
Full-scale Performance Evaluation of Mobile Roof Supports Barczak-TM; Gearhart-DF | In: Proceedings of the 16th International Conference on Ground Control in Mining, Peng SS, ed., Morgantown, WV: West Virginia University, 1997; :211-220	1997	Publication	Ground control
Proceedings: New Technology for Ground Control in Retreat Mining Mark-C; Tuchman-RJ | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 97-122, IC 9446, 1997 Mar: :1-129	1997	Publication	Ground control
Reducing the Risk of Ground Falls During Pillar Recovery Mark-C; Chase-FE; Pappas-DM | In: Yernberg WR, ed. Transactions of Society for Mining, Metallurgy, and Explorations, Inc., Vol. 314. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2003; :153-160	2003	Publication	Ground control
Retreat Mining Pillar Stability Mark-C | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin, 1998 Nov; :15	1998	Publication	Ground control
Sizing of Final Stumps for Safer Pillar Extraction Mark-C; Zelanko-JC | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :59-66	2001	Publication	Ground control
Technology News 464 - Analysis of Retreat Mining Pillar Stability (ARMPS): Version 4.0 for Windows NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 464, 1997 Jul; :1-2	1997	Publication	Ground control
Analysis of Retreat Mining Pillar Stability (ARMPS) NIOSH | NIOSH, 2003 Aug, :software	2003	Software	Ground control

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Mitigating Ground Fall Hazards in Underground Stone Mines

Description of Problem

During 1986-1995, more than 20% of the fatalities in the U.S. stone mining industry occurred at underground operations. Large number deaths occurred during 1992-1993 when 14 stone industry fatalities occurred, of which 10 were in underground mines. Ground control problems were targeted for research because 8 of those 10 deaths were attributed to roof and rib falls. In the early 1990s, most stone mines were much smaller and lacked even the most basic levels of ground control.

NIOSH researchers collecting rock stability data in a limestone mine

Research and Development Activities

Before 1994, only the Mine Safety and Health Administration and the National Stone, Sand & Gravel Association focused on safety issues in stone mines. Most of their activities were geared toward surface quarries. However, over the last 10 years, NIOSH initiated a program to raise the awareness and application of sound ground control practices for underground stone mines. Three methods were used to achieve this goal: (1) increase the use of roof monitoring technology to warn of roof falls, (2) promote safe mine design layouts, and (3) transfer this knowledge, along with other common techniques, to control the ground through annual seminars and one-on-one interactions at the mine sites. The broadest measure of NIOSH's impact in lowering ground fall fatalities and injuries is the documented exposure (estimated 70%) to operators and miners working in the underground stone sector since 1999.

Description of Intermediate Outcome

Following a rash of ground fall injuries in the early 1990s, NIOSH became active in promoting sound engineering safety practices in the underground stone industry. NIOSH researchers observed that this industry was not using the most advanced monitoring and design technology to control its fall-of-ground problems as practiced in other underground mining sectors. To this end, roof fall forecasting techniques were promoted and improved upon, producing more monitoring activities at mine sites than in past years. In addition, innovative mine layout designs were researched and implemented at several underground mine sites. These new designs have resulted in safer engineered mine layouts with less hazardous ground conditions. Finally, an extensive technology transfer program was initiated that included the annual Safety Seminar for Underground Stone Mines, mine site visits, and technical publications. All of these promote the safest practices and procedures for controlling hazardous ground conditions.

Outputs

31 Outputs

Title	Year	Output Type	Strategic Goal
100 Years of Improvement in Aggregate Worker Safety Iannacchione-A; Mucho-T | Stone, Sand and Gravel Review 2003 Mar; :28-34	2003	Publication	Surveillance and training
An Examination of the Loyalhanna Limestone's Structural Features and their Impact on Mining and Ground Control Practices Iannacchione-AT; Coyle-PA | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :218-227	2002	Publication	Ground control
An Overview of Groundfall Injuries and Worker Activity in Underground Stone Mines Pappas-DM; Prosser-LJ Jr | MSHA Holmes Safety Association Bulletin, 2001 Aug:8-14	2001	Publication	Ground control
Analysis of Pillar Design Practices and Techniques for U.S. Limestone Mines Iannacchione-AT | In Trans Inst Min Metall, (Sec A: Mining Industry), 1999 Dec 108(Sept-Dec):A152-A160	1999	Publication	Ground control
Application of Ground Penetrating Radar to Assess Ground Control Problems in Two Underground Limestone Mines Trevits-MA; Monaghan-WD; Mucho-TP | In: Proceedings of the Symposium on the Application of Geophysics to Environmental and Engineering Problems (SAGEEP 2004). Denver, CO: Environmental and Engineering Geophysical Society 2004; :788-805	2004	Publication	Ground control
Behavior of a Limestone Roof Supported by Spot Bolting Dolinar-DR; Mucho-TP | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin 1999 Mar; :19	1999	Publication	Ground control
Considerations for Using Roof Monitors in Underground Limestone Mines in the USA Prosser-LJ; Marshall-TE; Tadolini-SC; Iannacchione-AT; Banta-C | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2003 Aug; :119-126	2003	Publication	Ground control
Controlling Roof Beam Failures From High Horizontal Stresses in Underground Stone Mines Iannacchione AT, Dolinar DR, Prosser LJ Jr., Marshall TE, Oyler DC, Compton CS | In: Aziz NI, Indraratna B, eds. Proceedings of the International Conference on Geomechanics/Ground Control in Mining and Underground Construction, Wollongong, New South Wales, Australia: University of Wollongong, Vol. 2, 1998; :525-541	1998	Publication	Ground control
Controlling Roof Beam Failures From High Horizontal Stresses in Underground Stone Mines Iannacchione-AT; Dolinar-DR; Prosser-LJ; Marshall-TE; Oyler-DC; Compton-CS | In: Proceedings of the 17th International Conference on Ground Control in Mining, Peng SS, ed., Morgantown, WV: University of West Virginia, 1998 Aug 4-6, 1998 Aug; :102-112.	1998	Publication	Ground control
Failure Characteristics of Roof Falls at an Underground Stone Mine in Southwestern Pennsylvania Iannacchione-AT; Marshall-TE; Prosser-LJ, Jr | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :119-125	2001	Publication	Ground control
High Stress Mining Under Shallow Overburden in Underground U.S. Stone Mines Iannacchione-AT; Dolinar-DR; Mucho-TP | In: Proceedings of the First International Seminar on Deep and High-Stress Mining. Nedlands, Australia: Australian Centre for Geomechanics, section 32, 2002 Nov; :1-11	2002	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Investigation of Pillar-Roof Contact Failure in Northern Appalachian Stone Mine Workings Esterhuizen-GS; Iannacchione-AT | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2004 Aug; :320-326	2004	Publication	Ground control
Mapping Hazards with Microseismic Technology to Anticipate Roof Falls - A Case Study Iannacchione-AT; Batchler-T; Marshall-TE | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University,2004 Aug; pp. 327-333	2004	Publication	Ground control
Pillar Design Issues for Underground Stone Mines Iannacchione-AT | In: Proceedings of the 18th International Conference on Ground Control in Mining, Peng SS, Mark C, eds.,Morgantown, WV: West Virginia University, 1999 Jan; :271-281	1999	Publication	Ground control
Preventing Injuries Caused by Unrecognized Stone Mine Roof Beam Failures With a Pro-Active Roof Control Plan Iannacchione-AT; Prosser-LJ; Grau-R; Oyler-DC; Dolinar-DR; Marshall-TE; Compton-CS | SME Preprint 99-87. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc. 1999 :1-10	1999	Publication	Ground control
Relationship of Roof Movement and Strata-induced Microseismic Emissions to Roof Falls Iannacchione-AT; Coyle-PR; Prosser-LJ Jr; Marshall-TE, Litsenberger-J | Min Eng 56(12):53-60	2004	Publication	Ground control
Remote Roof Stability Monitoring for Underground Nonmetal Mines Grau-RH III; Iannacchione-AT; Prosser-LJ Jr | In: Proceedings of the 1999 Structures Congress. Reston, VA: American Society of Civil Engineers,1999; :727-730	1999	Publication	Ground control
Roof and Rib Hazard Assessment for Underground Stone Mines Iannacchione-AT; Prosser-LJ Jr. | Mining Eng 50(2), 1998; :76-80	1998	Publication	Ground control
Roof and Rib Hazard Assessment for Underground Stone Mines Iannacchione-AT; Prosser-LJ Jr | SME preprint 97-113, 1997	1997	Publication	Ground control
Roof Monitoring Helps Prevent Injuries in Stone Mines Iannacchione-AT; Prosser-LJ Jr; Grau-RH III; Oyler-DC; Dolinar-DR; Marshall-TE; Compton-C | Min Eng 2000 Nov; 52(11):32-37	2000	Publication	Ground control
Roof Monitoring in Limestone - Experience with the Roof Monitoring Safety System (RMSS) Marshall-TE; Prosser-LJ Jr.; Iannacchione-AT; Dunn-M | In: Proceedings of the 19th International Conference on Ground Control in Mining, Peng SS, Mark C, eds., Morgantown, WV: West Virginia University, 2000 Jan; :185-191	2000	Publication	Ground control
Safer Mine Layouts for Underground Stone Mines Subjected to Excessive Levels of Horizontal Stress Iannacchione-AT; Marshall-TE; Burke-L; Melville-R; Litsenberger-J | Mining Engineering, 55(4), 2003 Apr; :25-31	2003	Publication	Ground control
Scaling Accidents in Underground Stone Mines Grau-RH III; Prosser-LJ Jr | Rock Products 100(1), 1997 Jan; 39-41	1997	Publication	Ground control
Stability of Underground Openings Adjacent to the Sink Hole at the NIOSH Lake Lynn Research Laboratory Dolinar-DR; Marshall-TE; Barczak-TM; Mucho-TP | 2003 SME Annual Meeting, Feb 24-26, Cincinnati, Ohio, preprint 03-154. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2003 Feb; :1-7	2003	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Technology News 455 - Roof Hazard Alert Modules NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 455, 1997 May; :1-2	1997	Publication	Ground control
Technology News 471 - Innovative Hazard Recognition Training for Underground Limestone Miners NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 471, 1998 May; :1-2	1998	Publication	Ground control; Surveillance and training
Technology News 475 - Roof Monitoring Safety System for Underground Stone Mines NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 475, 1998; :1-2	1998	Publication	Ground control
Technology News 481 - Update: Roof Monitoring Safety System for Underground Stone Mines NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 481, 2000 Jun; :1-2	2000	Publication	Ground control
The Long-term Performance of Surface Support Liners for Ground Control in an Underground Limestone Mine Pappas-DM; Barton-TM; Weiss-ES | In: Hadjigeorgiou J, ed. Proceedings of the Third International Seminar on Surface Support Liners: Thin Spray-On Liners, Shotcrete, and Mesh (Quebec City, Canada, August 25-26, 2003). Section 10, 2003 Aug; :1-22	2003	Publication	Ground control
The Relationship of Roof Movement and Strata-Induced Microseismic Emissions to Roof Falls Iannacchione-AT; Coyle-PR; Prosser-LJ; Marshall-TE; Litsenberger-J | 2004 SME Annual Meeting, Feb 23-25, Denver, Colorado, preprint 04-58. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004 Feb; :1-9	2004	Publication	Ground control
Workplace Solutions: Ground Fall Injuries in Underground Stone Mines NIOSH | Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2004-106, 2003 Nov; :1-4	2003	Publication	Ground control

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Mobile Roof Supports for Retreat Room-and-Pillar Mines

Description of Problem

Mobile roof support equipped with a load rate monitor

Historically, one of the most common mining methods used to extract coal from underground mines has been room-and-pillar mining in which a series of pillars is developed as a section is advanced and extracted on retreat. Although longwall mining has overtaken room-and-pillar mining in popularity, pillar recovery still accounts for about 10% of U.S. underground coal mining. In the past, pillar recovery has been associated with a disproportionate rate of roof fall fatalities. During 1980-1997, nearly 25% of all roof fall fatalities occurred on pillar sections. The main danger is premature caving of the roof at the face where mining crews are working to install wood posts as they extract the coal pillars.

Research and Development Activities

Research by NIOSH engineers in the 1980s resulted in the development of mobile roof supports (MRS). These remotely controlled, hydraulically operated systems support the mine roof during pillar extraction and replace the use of wooden posts. The successful demonstration of MRS technology led to their commercialization by the mining manufacturer, J. H. Fletcher and Co. However, the MRS did not provide critical feedback to workers of impending ground failure as do the wood posts, which begin cracking and "popping" under load. The Mine Safety and Health Administration asked that guidelines be developed for safe use of the MRS and that a warning system be developed to alert miners to impending roof caving. NIOSH developed and field tested a warning system for the MRS that would alert miners to unstable roof and pillar conditions during pillar mining. It provides a visual indication of current loading, as well as changes in loading on the MRS. An increase in load rate tells miners that the pillars are yielding and failing, and the loads that were once carried by the pillars are transferred to the MRS. This condition often triggers failure of the mine roof.

R&D Outputs and Transfer Activities

During 1997-2002, the results of this research, which includes both hardware and computer logic for MRS warning systems and guidelines for safe MRS use, were transferred to the mining industry through 7 technical papers and 12 presentations. This research was also presented at five MSHA/NIOSH-sponsored seminars.

Description of Intermediate Outcome

The use of MRSs in U.S. retreat mines has grown dramatically in recent years. In 1988, four MRSs were in use. The number has grown to about 270 currently in operation at 34 U.S. coal mines. However, six fatalities have occurred where MRSs were being used. In four of these fatalities, the miners were standing in the active intersection (an unsafe location) as the last lift was being mined or after it had been completed. The successful demonstration of the load-warning system resulted in the incorporation of this system into the design of the Fletcher MRS.

Field studies were also done to evaluate the safety and performance of MRSs under varying geologic conditions to provide data that MSHA and the mining industry could use to improve safety in retreat operations. The studies resulted in recommendations for optimum MRS setting pressures, optimum number of MRSs in a section, location of an MRS with respect to a continuous miner, pillar extraction method, and the need to orient the retreat panel to major joint sets to optimize caving.

Outputs

8 Outputs

Title	Year	Output Type	Strategic Goal
An Overview of Geomechanics Safety Research on Mobile Roof Supports Maleki-H; Owens-J | System Safety at the Dawn of a New Millennium. Proceedings, 17th International System Safety Conference, Orlando, FL, Aug 16-21, 1999. Unionville, VA: System Safety Society, 1999 Jan; :554-563	1999	Publication	Ground control
Analysis of the Interaction Between Mobile Roof Supports and Mine Strata Maleki-H; Owens-J | Design and Construction in Mining, Petroleum and Civil Engineering, 1998, Nov :287-293	1998	Publication	Ground control
Application of Computational and Statistical Techniques to an Evaluation of Mobile Roof Supports Maleki-H; Owens-J | In: S.S. Desai, T. Kundu, S. Hatpalani, D. Contractor, and J. Kemeny, eds. Computer Methods and Advances in Geomechanics. Proceedings of the Tenth International Conference on Computer Methods and Advances in Geomechanics (Jan 7-12, 2001; Tucson, AZ), Vol. 2, 2001; :1705-1711	2001	Publication	Ground control
Field Evaluation of Mobile Roof Support Technologies Maleki-H; Owens-J; Endicott-M | Paper in Proceedings: 20th International Conference on Ground Control in Mining, ed. By Syd S. Peng, Christopher Mark, and A. Wahab Khair (Morgantown WV, Aug. 7-9, 2001). WV University, Morgantown, WV, 2001; :67-77	2001	Publication	Ground control
Method and Apparatus for Load Rate Monitoring Howie-WL; Owens-JK | U.S. Patent No. 6,957,166 (granted Oct. 18, 2005)	2005	Patent	Ground control
Mobile Roof Support Load Rate Monitoring System Howie-WL; Owens-JK | Proceedings of the IEEE Industry Applications Society (Phoenix, AZ, October 3-7, 1999). Vol. 1, :234-239	1999	Publication	Traumatic injuries
Mobile Roof Support Safety Research - An Update Owens-J; Howie-W; Maleki-H | In: Jenkins FM, Langton J, McCarter MK, and Rowe B, eds. Proceedings: Thirtieth Annual Institute on Mining Health, Safety, and Research (Salt Lake City, UT, Aug. 8-11, 1999). Blacksburg, VA: Department of Mining and Minerals Engineering, Virginia Polytechnical Institute, 2001 Aug; :101-113	2001	Publication	Ground control; Traumatic injuries
Monitoring Mobile Roof Supports Hay-KE; Signer-SP; King-ME; Owens-JK | In: Mark-C PhD, Tuchman-RJ, eds. Proceedings: New Technology for Ground Control in Retreat Mining, US Bureau of Mines, Report of Investigations 9446, 1997; :89-98	1997	Publication	Ground control; Traumatic injuries

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

NIOSH Support Technology Optimization Program (STOP) Design Software

Description of Problem

New mine roof support products with distinct performance characteristics are developed each year. The performance characteristics and limitations of these support systems are evaluated through full-scale testing in the NIOSH mine roof simulator at the Pittsburgh Research Laboratory. This information provides the basis for which these support systems are considered for specific applications by mining companies and approved for use by the Mine Safety and Health Administration.

The NIOSH STOP software program is interactive and user driven to accomplish several support design requirements

Research and Development Activities

To facilitate the application of these technologies to improve mine safety, NIOSH developed the Support Technology Optimization Program (STOP). STOP is a Window´s-based software program that provides mine operators with a simple and practical tool to make engineering decisions about the selection and placement strategy of these various mine roof support technologies.

R&D Outputs and Transfer Activities

Training workshops on the use of the STOP software have been held in Pennsylvania, West Virginia, Virginia, Kentucky, Illinois, Indiana, Colorado, and Utah. To date, about 1,000 copies of the STOP software program have been distributed through these technology transfer seminars and from software downloads on the NIOSH webpage. The program has been used internationally in Mexico, the United Kingdom, Germany, Australia, and the Republic of South Africa.

Description of Intermediate Outcome

The performance testing of new support products in the NIOSH mine roof simulator and the implementation of this information into the STOP design software has eliminated the trial-and-error approach to new support technologies that was common in the past. This provides insurance toward successful support applications without exposing miners to uncertain, potentially hazardous support performance. STOP can provide an engineering foundation to ensure that inadequate support designs, as well as ultraconservative support applications, are avoided. Safety will be improved by matching support performance to mine conditions. This reduces the likelihood of roof falls and

blocked travel and escapeways. Material handling injuries associated with support construction account for about 5,000 lost workdays per year in U.S. underground coal mines. STOP can help define the material handling advantages of alternative support technologies that use lighter-weight materials or systems that can be installed with mechanical-assist equipment.

Outputs

11 Outputs

Title	Year	Output Type	Strategic Goal
Investigation of the Jacking Force Capability of Tunnel Liners Barczak-TM; Smith-R | 2002 SME Annual Meeting, Feb 25-27, Phoenix, Arizona, preprint 02-186. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2002 Feb; :1-13	2002	Publication	Ground control
Load and Deflection Response of Ventilation Stoppings to Longwall Abutment Loading: A Case Study Oyler-DC; Hasenfus-G; Molinda-GM | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :34-41	2001	Publication	Ground control
Mistakes, Misconceptions, and Key Points Regarding Secondary Roof Support Systems Barczak-TM | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :347-356	2001	Publication	Ground control
Numerical Modeling for Increased Understanding of the Behavior and Performance of Coal Mine Stoppings Burke-LM; Iannacchione-AT; Barczak-TM; Westman-EC | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining (August 3-5, 2004). Morgantown, WV: West Virginia University, 2004; :112-118	2004	Publication	Ground control
Optimizing Secondary Roof Support with the NIOSH Support Technology Optimization Program (STOP) Barczak-TM | In: Proceedings of the 19th International Conference on Ground Control in Mining,Peng SS, Mark C, eds., Morgantown, WV: West Virginia University, August 8-10, 2000 Aug; :74-83	2000	Publication	Ground control
Performance and Safety Considerations of Hydraulic Support Systems Barczak-TM; Gearhart-DF | In: Proceedings of the 17th International Conference on Ground Control in Mining, Peng SS, ed., Morgantown, WV: University of West Virginia, 1998 Aug; :176-186	1998	Publication	Ground control
Performance Characteristics of Wood Cribs and Alternative Roof Support Technologies Barczak-TM | NIOSH Internal Report 4944	2000	Publication	All
Pumpable Roof Supports: Developing Design Criteria by Measurement of the Ground Reaction Curve Barczak-TM; Chen-J; Bower-J | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2003 Aug; :283-294	2003	Publication	Ground control
The Effect of Standing Support Stiffness on Primary and Secondary Bolting Systems Tadolini-SC; Barczak-TM; Zhang-Y | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2003 Aug; pp. 300-307	2003	Publication	Ground control
Updating the NIOSH Support Technology Optimization Program (STOP) With New Support Technologies and Additional Design Features Barczak-TM | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :337-346	2001	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Support Technology Optimization Program (STOP) NIOSH	2004	Software	Ground control

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Preventing Longwall Tailgate Blockages

Description of Problem

Safe longwall mining depends on maintaining ground control in the gate entries. These are the lifelines that provide access to the longwall face. When a gate entry is blocked by rock falls, miners must use their emergency escape route. At the Wilberg mine fire in Utah in 1984, 27 miners were killed from carbon monoxide poisoning that may have been exacerbated by a roof fall in the longwall tailgate entry. The tailgate entry is essential for maintaining adequate ventilation on the longwall mining face. It also serves as the secondary escapeway in the event of a mine disaster.

A brittle failure of a concrete tailgate support

Research and Development Activities

NIOSH scientists realized that maintaining safe tailgates would require an integrated approach that considered not only pillar design, but also roof rock quality and roof support. One research effort used an innovative method based on multivariate statistical analysis of a comprehensive database of mining case histories. The results of this effort were implemented in the Analysis of Longwall Pillar Stability (ALPS) computer program. A second research effort focused on fostering improved roof support technology to replace wood cribs. Numerous new support concepts were tested in the mine roof simulator (MRS) at the Pittsburgh Research Laboratory, which provided detailed information on their performance characteristics. These test results also provided the basis for the Support Technology Optimization Program (STOP) computer program.

R&D Outputs and Transfer Activities

The ALPS design guidelines, the STOP program, and the performance testing of new tailgate roof supports have been the subject of numerous open industry briefings, industry short courses, and hands-on computer training sessions. These continue to be requested on a regular basis.

Description of Intermediate Outcome

Today, nearly every U.S. longwall has replaced wood cribs with modern supports tested in the MRS and inputted into the STOP design program. More than 40 new types of tailgate supports have been commercialized in the United States. The rapid spread of this new technology can be attributed in large part to the impartial scientific credibility of the performance testing done by NIOSH. In

addition, the ALPS method, combined with support systems designed using the STOP program, has become the industry standard for longwall pillar and support design. Thousands of copies of the computer program have been requested, and the program is used routinely by U.S. longwall coal operators. The Mine Safety and Health Administration and state regulatory agencies make extensive use of ALPS and STOP. It is also part of the curriculum at mining schools, including West Virginia University, Virginia Polytechnic Institute and State University, The Pennsylvania State University, and Southern Illinois University. In addition, ALPS has received considerable attention abroad. A project under the Australian Coal Association Research Program was funded to calibrate the ALPS method for Australian conditions. The resulting Analysis of Longwall Tailgate Stability is now the standard for Australian longwall mines.

Outputs

14 Outputs

Title	Year	Output Type	Strategic Goal
Calibration of the Analysis of Longwall Pillar Stability (ALPS) Chain Pillar Design Methodology for Australian Conditions Colwell-M; Frith-RC; Mark-C | In: Proceedings of the 18th International Conference on Ground Control in Mining, Peng SS, Mark C, eds., Morgantown, WV: West Virginia University,1999; :282-290	1999	Publication	Ground control
Design Methodology for Standing Secondary Roof Support in Longwall Tailgates Mucho-TP; Barczak-TM; Dolinar-DR; Bower-J; Bryja-JJ | In: Proceedings of the 18th International Conference on Ground Control in Mining, Peng SS, Mark C, eds., Morgantown, WV: West Virginia University, 1999; :136-148	1999	Publication	Ground control
Hydraulic Prestressing Units: An Innovation in Roof Support Technology Barczak-TM; Tadolini-SC; McKelvey-P | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, August 3-5, 2004; :286-294	2004	Publication	Ground control
In the Field - Cribs Versus Cables Mucho-TP | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin, 1998 Mar; :5-6	1998	Publication	Ground control
Longwall Tailgate Support: Consideration, Design, and Experience Barczak-TM; Mucho-TP; Dolinar-D; Bower-J; Bryja-J | In: Proceedings of Longwall USA International Exhibition & Conference, 1999; :79-104	1999	Publication	Ground control
Longwall Tailgates: the Technology for Roof Support has Improved, but Optimization is Still Not There Barczak-TM | In: Proceedings of Longwall USA (Pittsburgh, PA, June 3-5, 2003), 2003 Jun; :105-130	2003	Publication	Ground control
Performance of Various Standing and Cribless Tailgate Support Configurations in a Large Eastern Coal Mine Molinda-GM; Dolinar-DR; Barczak-TM; Hustus-J | In: Proceedings of the 16th International Conference on Ground Control in Mining, Peng SS, ed., Morgantown, WV: West Virginia University, 1997; :9-15	1997	Publication	Ground control
Proceedings of the Second International Workshop on Coal Pillar Mechanics and Design Mark-C; Heasley-KA; Iannacchione-AT; Tuchman-RJ, eds. | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Pub No. 99-114, Information Circular 9448, 1999	1999	Publication	Ground control
Standing Support Alternatives in Western Longwalls Barczak-TM; Tadolini-SC | 2005 SME Annual Meeting, February 28 - March 2, Salt Lake City, Utah, preprint 05-78. Littleton, CO, Society for Mining, Metallurgy, and Exploration, Inc., 2005 Feb; :1-10	2005	Publication	Ground control
Technology News 467 - Wood Crib Performance Model NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH 1997 Nov; :1-2	1997	Publication	Ground control
Technology News 492 - Proceedings of the Second International Workshop on Coal Pillar Mechanics and Design NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 492, 2001 Aug; :1-2	2001	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Analysis of Longwall Pillar Stability (ALPS) Mark-C | NIOSH, 2003 Aug, :software	2003	Software	Ground control
Coal Mine Roof Rating (CMRR) NIOSH | NIOSH 2004 Dec; :Software	2004	Software	Ground control
Support Technology Optimization Program (STOP) NIOSH	2004	Software	Ground control

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Preventing Massive Coal Pillar Collapses

Description of Problem

During the decade prior to 1998, massive pillar collapses occurred in 12 U.S. underground coal mines. In each incident, the resulting airblast caused major damage throughout the mine. Fortunately, there were no fatalities, although a number of miners were injured. Massive pillar collapses are a major threat to the safety of miners. In 1960, more than 400 miners were killed in a South African coal mine when the pillars collapsed. A pillar collapse in a U.S. trona mine in 1995 also caused a fatality.

Massive pillar collapses can hurl 30 pound cinder blocks over 500 feet through the mine workings and blow out ventilation stoppings

Research and Development Activities

NIOSH research focused on determining why sudden, violent collapse occurred in these cases rather than the more typical "slow squeeze" failure. The cause was linked to the unique failure mechanics of slender coal pillars in particular geologic environments. The research findings were the basis for guidelines for mine design to avoid these massive pillar collapses. The NIOSH-developed Analysis of Retreat Mining Pillar Stability (ARMPS) computer program is a key component of the guidelines. The guidelines also consider pillar width-to-height ratios, the use of barrier pillars, and panel size.

R&D Outputs and Transfer Activities

The guidelines have been transmitted to the mining community through a combination of open industry briefings, industry ground control short courses, Preventative Roof-Rib Outreach Program (PROP) seminars, and other venues. Of particular importance has been the effort to educate Mine Safety and Health Administration's (MSHA) Tech Support personnel, MSHA roof control specialists, and district personnel as to the hazards of massive pillar collapses and the preventive measures.

Description of Intermediate Outcome

MSHA has been using the NIOSH-based guidelines and preventative measures to evaluate mine roof control plans since 1998. This proactive approach has eliminated these catastrophic-type failures, as no further collapses have taken place since then.

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
Design Methods to Control Violent Pillar Failures in Room-and-Pillar Mines Zipf-RK Jr.; Mark-C | Transactions of the Institution of Mining and Metallurgy 106(Sept-Dec), 1997; :A124-A132	1997	Publication	Ground control
Proceedings of the Second International Workshop on Coal Pillar Mechanics and Design Mark-C; Heasley-KA; Iannacchione-AT; Tuchman-RJ, eds. | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Pub No. 99-114, Information Circular 9448, 1999	1999	Publication	Ground control
Technology News 492 - Proceedings of the Second International Workshop on Coal Pillar Mechanics and Design NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 492, 2001 Aug; :1-2	2001	Publication	Ground control
Analysis of Retreat Mining Pillar Stability (ARMPS) NIOSH | NIOSH, 2003 Aug, :software	2003	Software	Ground control

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Reducing Rock Fall Injuries to Coal Miners

Description of Problem

Rock falls in coal mines cause serious injuries to miners nearly every working day. In recent years, about 500 injuries annually have resulted from rock falls. Often these injuries are quite serious, resulting in an average of 50 days of lost time. These injuries are not caused by major roof falls. Rather, they occur when small pieces of rock fall from between the primary roof supports (roof bolts) or around the automated temporary roof support. Small rock falls have also caused one or two fatalities in almost each of the past 5 years.

Research and Development Activities

NIOSH research has shown that most rock fall injuries can be prevented by using surface controls. These include straps, large plates, and, in particular, wire mesh (roof screen). To help increase the use of surface controls, NIOSH has conducted an intensive research/educational program aimed at:

- Making the coal mining community aware of the magnitude of the rock fall problem;
- Identifying and publicizing "best practices" for preventing rock falls through the use of surface controls; and
- Attempting to change the mining industry culture, which currently accepts a certain level of risk of rock fall injury beneath supported roof.

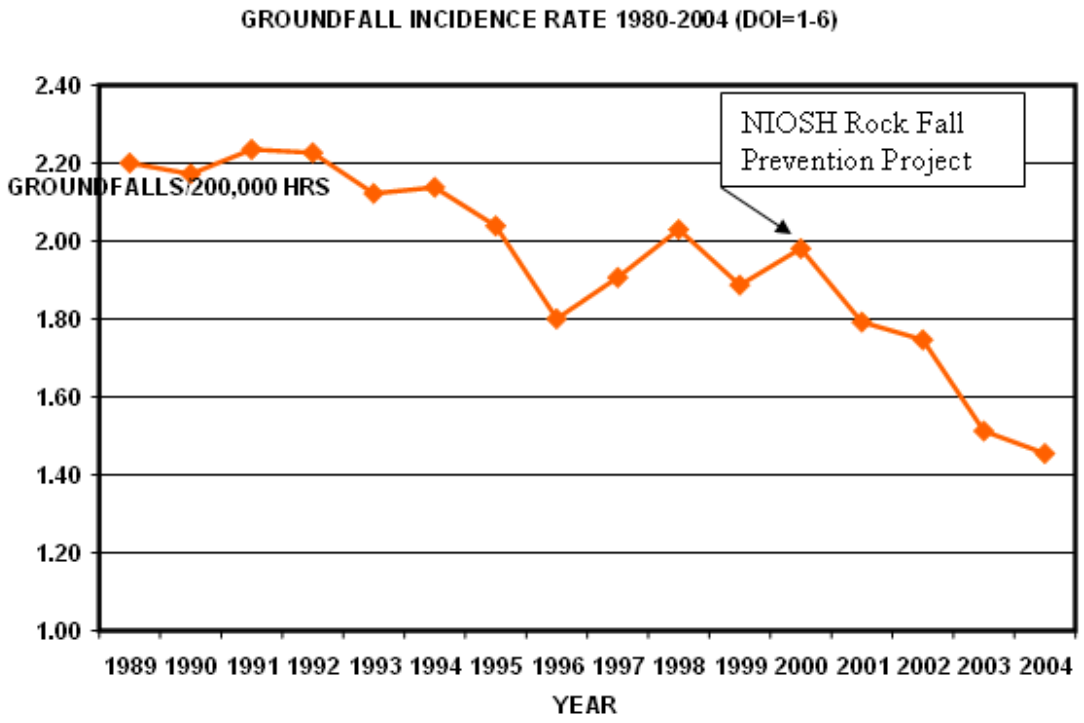
Research has included extensive analysis of rock fall injury data, in-mine studies of the effectiveness of different surface control techniques, and evaluations of the geologic conditions associated with rock falls. In addition, a new surface control called the personal bolter screen (PBS) was developed for thinner seams and other situations where traditional full screen might not be appropriate.

R&D Outputs and Transfer Activities

The educational effort began with a series of technical papers presented at a broad range of ground control, mining engineering, and mine safety audiences. Numerous visits were made to mines that were at particularly high risk for rock falls. An ongoing partnership with the Mine Safety and Health Administration, exemplified by NIOSH's co-sponsorship of the Preventative Roof/Rib Outreach Program (PROP) effort, has provided another crucial vehicle for information transfer. Most recently, a 7-minute video entitled Make It Safer With Roof Screen was developed. It has been very well received, with more than 200 copies requested in the United States. The PBS has been made commercially available by two major roof support manufacturers.

Description of Intermediate Outcome

Prior to 2000, when NIOSH initiated its rock fall prevention initiative, the rock fall injury rate in U.S. underground coal mines had held relatively steady for at least 6 years. It has now fallen in each of last 4 years to a level about 25% below its former plateau. The improvement can be attributed in part to an increased awareness of the rock fall problem and an increased use of surface control systems. NIOSH believes that further major improvements in the rock fall injury rate can still be obtained because the use of screen and of the PBS has not yet increased to its fullest potential.



Outputs

16 Outputs

Title	Year	Output Type	Strategic Goal
Application of Ground Penetrating Radar to Evaluate the Extent of Polyurethane Grout Infiltration for Mine Roof Control: A Case Study Monaghan-WD; Trevits-MA | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University; :197-204	2004	Publication	Ground control
Best Practices and Bolting Machine Innovations for Roof Screening Robertson-SB; Molinda-GM; Dolinar-DR; Pappas-DM; Hinshaw-GE | 2003 SME Annual Meeting, Feb 24-26, Cincinnati, Ohio, preprint 03-158. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :1-8	2003	Publication	Ground control
Best Practices to Mitigate Injuries and Fatalities from Rock Falls Mark-C; Iannoacchione-AT | In: Proceedings of the 31st Annual Institute of Mining Health, Safety and Research, Bockosh GR, Karmis M, Langton J, McCarter MK, Rowe B, eds., Blacksburg, VA: Virginia Polytechnic Institute and State University, Department of Mining and Minerals Engineering, 2000; :115-130	2000	Publication	Ground control
Covering the Roof Reduces Crippling Injuries Underground Molinda-GM; Robertson-SB; Mark-C; Dolinar-DR | Coal Age 108(11-12), 2003; :20-22, 26	2003	Publication	Ground control
Deep-cut Ground Control and Worker Safety in Coal Mines Bauer-ER; Bise-CJ | SME preprint 99-109. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 1999	1999	Publication	Ground control
Developments in Sealant Support Systems for Ground Control Pappas-DM; Barton-TM; Weiss-ES | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :344-353	2002	Publication	Ground control
Enhanced Surface Control for Roof and Rib Support Tadolini-SC; Dolinar-DR | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :173-179	2001	Publication	Ground control
Evaluation of Polyurethane Injection for Beltway Roof Stabilization in a West Virginia Coal Mine Molinda-GM | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining, August 3-5, 2004. Morgantown, WV: West Virginia University, 2004 Aug; :190-196	2004	Publication	Ground control
Factors Influencing Intersection Stability in U.S. Coal Mines Molinda-G; Mark-C; Bauer-E; Babich-D; Pappas-D | In: Proceedings of the 17th International Conference on Ground Control in Mining, Peng SS, ed., Morgantown, WV: University of West Virginia, 1998 Aug; pp. 267-275	1998	Publication	Ground control
Proceedings: New Technology for Coal Mine Roof Support Mark-C; Dolinar-DR; Tuchman-RJ; Barczak-TM; Signer-SP; Wopat-PF, eds. | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2000-151, IC 9453; :1-280	2000	Publication	Ground control
Roof Screening: Best Practices and Roof Bolting Machines Robertson-SB; Hinshaw-GE | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002; :189-194	2002	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Safety Improvements for Roof Bolter Operators Robertson-SB; Cooper-DP; Wiehagen-WJ | In: Proceedings of the American Society of Safety Engineers Professional Development Conference (Las Vegas, NV, June 7-10, 2004). Des Plaines, IL American Society of Safety Engineers, 2004 Jun; :1-17	2004	Publication	Ground control
Skin Failure of Roof and Rib in Underground Coal Mines Bauer-ER; Pappas-DM; Dolinar-DR; McCall-FE; Babich-DR | In: Peng SS, Mark C, eds. Proceedings of the 18th International Conference on Ground Control in Mining, Morgantown, WV: West Virginia University, 1999; :108-114	1999	Publication	Ground control
Technology News 493 - Proceedings: New Technology for Coal Mine Roof Support NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 493, 2001 Aug :1-2	2001	Publication	Ground control
Technology News 508 - NIOSH Releases New Safety Video: Make It Safer With Roof Screen NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 508, 2005 Mar; :1-2	2005	Publication	Ground control
Make it Safer with Roof Screen NIOSH | NIOSH 2004 Jan; :Video (RealMedia format)	2004	Video	All

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Rock Burst Control in Deep Metal Mines

Description of Problem

Mines in the Coeur d'Alene Mining District have a fatality rate eight times greater than the mining industry average for all causes of death. Ore from the platinum mines in Montana is being extracted from greater depths, and conditions that favor rock bursts are being encountered. Currently, five underground hard-rock mines in the United States have geologic and mining conditions that could generate rock bursts. In 2003, these mines employed 2,205 (19%) of the 11,549 operators and contract workers in underground metal/nonmetal mining.

Research and Development Activities

The NIOSH mining program is continuing research that began under the U.S. Bureau of Mines to monitor, study, and control rock bursts in deep metal mines. Great strides have been made in understanding the basic mechanisms of different types of bursts. The development of seismic monitoring systems tailored to mine-scale events has provided mine personnel with a tool to measure how underground mines respond to stress changes brought on by excavation. This monitoring technology allows mine stability information to be conveyed to miners working underground, as well as to engineers and management, and incorporated into daily and long-term operations planning for worker safety. Monitoring data have also been used by NIOSH to guide the development of ways to reduce worker exposure to underground hazards. For example, this research led to adapting the underhand mining method and specialized support systems to decrease rock burst fatalities dramatically in deep-vein mines in Idaho.

R&D Outputs and Transfer Activities

During 1997-2005, this research was transferred to the mining industry through 31 technical papers and presentations. Eighty percent of the mines that are experiencing rock burst problems have cooperated in the research and adopted the technology.

Description of Intermediate Outcome

After the underhand mining method was first implemented at the Lucky Friday Mine in the late 1980´s not one rock burst fatality has occurred. Without this work, the mine would have been forced to close permanently because of the rock burst danger. Work continues to develop this method and assist mines in adopting these and other life-saving ground support measures. NIOSH recently assisted two burst-prone mines to adopt the underhand mining method in combination with a weakly cemented backfill as support. In 2001, the Galena Mine switched from overhand cut-and-fill

to underhand methods in burst-prone stopes, as recommended by NIOSH. In 2002, the Stillwater Mine adopted these methods for the more burst-prone parts of its mine. These and other NIOSH-recommended measures have greatly reduced the vulnerability of miners to rock burst collapse. These outcomes are the result of a long-standing research effort begun in the 1950s.

Proper application of rock burst safety measures, like any prescription, can only succeed where the problem is properly diagnosed. Researchers at NIOSH have built on a long-standing program of mine monitoring to advise mines on technology for diagnosing the nature of rock bursts as well as detecting incipient hazards. A number of rock burst-prone mines have installed these monitoring systems, including the Galena, Meikle, East Boulder and Stillwater mines. Regional sensors and the Stillwater Mine system set up by NIOSH have recently detected the onset of rock bursting at that mine.

The rock-burst problem and long-standing efforts by NIOSH researchers to reduce the risks of injuries and fatalities have been recognized on a number of occasions by the local press. Too often this coverage has been prompted by fatal accidents.

- Kramer B [1999]. Danger around every corner. Spokesman Review, Feb 21.
- The Olympian [2001]. Spokane lab puts miners' safety first, May 15 (this article highlighted rock burst and haul truck work).
- Silverman J [2001]. Silver valley mourns two miners. Spokesman Review, Jun 7.

Outputs

27 Outputs

Title	Year	Output Type	Strategic Goal
60 Years of Rockbursting in the Coeur D'Alene District of Northern Idaho, USA: Lessons Learned and Remaining Issues Whyatt-J; Blake-W; Williams-T; White-B | Presentation at 109th Annual Exhibit and Meeting, Society for Mining, Metallurgy, and Exploration, Feb. 25-27, 2002, Phoenix, AZ. Preprint 02-164; :10 pp	2002	Publication	Ground control
A Method for Modeling Variation of In Situ Stress Related to Lithology Whyatt-JK | In: Elsworth D, Tinnucci JP, Heasley KA, eds. Rock Mechanics in the Public Interest. Proc 38th U.S. Rock Mechanics Symposium, DC Rocks, Vol. 2 (Washington, DC, July 7-10, 2001), Rotterdam: Balkema, 2001 Jul; :1087-1094	2001	Publication	Ground control
Classification of Large Seismic Events at Lucky Friday Mine Whyatt-JK; Blake-W; Williams-TJ | Transactions of the Institution of Mining and Metallurgy (Section A: Mining Industry), vol. 106, Sept.-Dec. 1997; :A148-A162	1997	Publication	Ground control
Coeur d'Alene Mining District: Product of Preconcentrated Source Deposits and Tectonism Within the Lewis and Clark Line White-B | In: Roberts S, Winston D, eds. Geologic Field Trips, Western Montana and Adjacent Areas. University of Montana, Missoula, and Western Montana College of the University of Montana, Dillon, pp. 95-102	2000	Publication	Ground control
Comparison of Seismic Tomography, Strain Relief, and Ultrasonic Velocity Measurements to Evaluate Stress in an Underground Pillar Scott-DF; Girard-JM; Williams-TJ; Denton-DK | Society for Mining, Metallurgy, and Exploration, Inc. (SME) Annual Meeting (Mar 1-3, 1999; Denver, CO); SME Preprint 99-155	1999	Publication	Ground control
Differential Wall Rock Movements Associated with Rock Bursts, Lucky Friday Mine, Coeur d'Alene Mining District, Idaho, USA White-BG; Whyatt-JK | In: Armadei, Kranz, Scott & Smeallie, eds. Rock Mechanics for Industry. Proceedings of the 37th U.S. Rock Mechanics Symposium (Vail, CO, June 6-9, 1999), 1999 Balkema, Rotterdam, ISBN 90 5809 052 3, Balkema, 1999 Jun; :1051-1059	1999	Publication	Ground control
Diverse Tectonism in the Coeur d'Alene Mining District White-BG | Butte, MT: Montana Bureau of Mines and Geology, Spec. Pub. 112, pp. 254-265	1997	Publication	Ground control
Geomechanics of Reinforced Cemented Backfill in an Underhand Stope at the Lucky Friday Mine, Mullan, Idaho Williams-TJ; Denton-DK; Larson-MK; Rains-RL; Seymour-JB; Tesarik-DR | Spokane, WA: US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2001-138, Report of Investigations 9655, 2001 Jul :1-18	2001	Publication	Ground control
Ground Conditions and the May 13, 1994, Rock Burst, Coeur d'Alene Mining District, Northern Idaho Whyatt-JK.; Williams-TJ; White-BG | In: J. Girard, M. Leibman, C. Breeds, and T. Doe, eds. Pacific Rocks 2000. Rock Around the Rim: Proceedings of the Fourth North American Rock Mechanics Symposium (NARMS 2000) (July 31-Aug. 3, 2000; Seattle WA), Balkema, 2000; :313-318	2000	Publication	Ground control
Interaction Between Wall Rock Closure, Cemented Backfill Load, and Reinforcement Bolt Load in an Underhand Stope at the Lucky Friday Mine Williams, T.J., D. Denton, J.B. Seymour, D. Tesarik, C. Peppin, and D. Bayer | In: D Stone, ed., Minefill 2001: Proceedings of the 7th International Symposium on Mining with Backfill, Soc. For Min., Metall, and Explor., Littleton, CO, 2001; :117-125	2001	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Investigation of a Rock-Burst Site, Sunshine Mine, Kellogg, Idaho Scott-DF; Williams-TJ; Friedel-MJ | In: Gibowicz SJ, Lasocki S, eds., Proceedings of the 4th International Symposium on Rockbursts and Seismicity in Mines, Balkema, 1997; :311-315	1997	Publication	Ground control
Mechanics of a Large, Strain-Type Rock Burst and Design for Prevention White-BG; Williams-TJ; Whyatt-JK | In: Hammah R, Bawden W, Curran J, Telesnicki M, eds. NARMS-TAC 2002: Mining and Tunnelling Innovation and Opportunity. Vol 2. Toronto, Ontario, Canada: Univ. of Toronto, Toronto, July 7-10, 2002; :1095-1100	2002	Publication	Ground control
Monitoring of Reinforced Cemented Backfill in an Underhand Stope Williams, T., D. Denton, C. Peppin, and D. Bayer | In: J. Girard, M. Leibman, C. Breeds, and T. Doe, eds. Pacific Rocks 2000. Rock Around the Rim: Proceedings of the Fourth North American Rock Mechanics Symposium (NARMS 2000) (July 31-Aug. 3, 2000; Seattle, WA), Balkema, 2000; :387-393	2000	Publication	Ground control
New Tricks for an Old Elephant: Revising Concepts of Coeur d'Alene Geology White-BG | Min Eng 1998 Jan; :50(8)27-35	1998	Publication	Ground control
New Tricks for an Old Elephant: Revising Concepts of Coeur d'Alene Geology White-BG | SME preprint 98-87. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., pp. 1-11	1998	Publication	Ground control
Origin of Mining-Induced Fractures Through Macroscale Distortion White-BG; Larson-M; Iverson-SR | Gulf Rocks 2004: Proceedings, Rock Mechanics Across Borders & Disciplines, s6th North American Rock Mechanics Conference, June 5-10, 2004, Houston, Texas. Report No. ARMA/NARMS 04-569. Alexandria, VA: American Rock Mechanics Association, 2004 Jun; :1-8	2004	Publication	Ground control
P-Wave Signal IDs Stressed Rock in Deep Mines Williams-TJ; Scott-DF | Sensors, The Journal of Applied Sensor Technology, vol. 15, no. 2, 1998 Feb; :12-13	1998	Publication	Ground control
Relative Stress Conditions in an Underground Pillar, Homestake Mine, Lead, SD Scott-DF; Williams-TJ; Freidel-MJ; Denton-DK | Proceedings of the 36th U.S. Rock Mechanics Symposium. New York, NY: Columbia University, Paper No. 278, 1997	1997	Publication	Ground control
Remote Monitoring of Mine Seismicity and Earthquakes Using Radio Telemetry, Computers, and the Internet Denton-D; Stickney-M; Williams-T; Langston-R | In: R.K. Singhal, K. Fytas, and C. Chiwetelu, eds., Computer Applications in the Minerals Industries, Proceedings of the Fourth International Conference on Computer Applications in the Minerals Industries (CAMI 2003) (Sept. 8-10, 2003; Calgary, AB), 2003 Sep	2003	Publication	Ground control
Rock Bursting and Seismicity During Ramp Development, Lucky Friday Mine, Mullan, Idaho Whyatt-JK; White-BG | In: Peng SS, ed. Proceedings of the 17th International Conference on Ground Control in Mining, 1998 Aug :317-325	1998	Publication	Ground control
Role of Fault Slip on Mechanisms of Rock Burst Damage, Lucky Friday Mine, Idaho, USA White-BG; Whyatt-JK | In: Hogan TO, ed. SARES 99 - Second Southern African Rock Engineering Symposium. Implementing Rock Engineering Knowledge September 13-15, Johannesburg, S. Africa. Lisboa, Portgual: International Society of Rock Mechanics 1999 Jan; :169-178	1999	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Shear Mechanism for Mining-Induced Fractures Applied to Rock Mechanics of Coal Mines White-B | In: Peng SS, Mark C, Wahab A, and Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining (Morgantown, WV, Aug. 6-8, 2002), West Virginia University, Morgantown, WV, 2002 Aug; :328-334	2002	Publication	Ground control
Shear Origin of Tension in Excavation-Induced Fractures White-BG; Iverson-S; Larson-M | In: Culligan PJ, Einstein HH, Whittle AJ, eds. Soil and Rock America 2003. 12th Panamerican Conference on Soil Mechanics and Geotechnical Engineering and the 39th U.S. Rock Mechanics Symposium, Vol. 1. Cambridge, MA: Massachusetts Institute of Technology, 2003 Jun; 1:909-916	2003	Publication	Ground control
Stratigraphic Subunits and Control of Ground in The Revett Formation, Coeur d'Alene Mining District, Idaho Whyatt-JK; White-BG | Proceedings of the 36th U.S. Rock Mechanics Symposium. New York, NY: Columbia University, paper No. 332, 1997	1997	Publication	Ground control
Stratigraphy of the Proterozoic Revett Formation and its Control on Ag-Pb-Zn Vein Mineralization in the Coeur d'Alene District, Idaho Mauk-JL; White-BG | Econ Geol 99:295-312	2004	Publication	Ground control
Structural Stress and Concentration of Mining-Induced Seismicity Whyatt-JK; White-BG; Blake-W | Trans SME, Vol. 300,1997; :74-82	1997	Publication	Ground control
The Lewis and Clark Line and Coeur d'Alene Mining District White-B; Winston-W; Lange-I | In: Roberts S, Winston D, eds. Geologic Field Trips, Western Montana and Adjacent Areas. University of Montana, Missoula, and Western Montana College of the University of Montana, Dillon, pp. 103-122	2000	Publication	Ground control

Strategic Program Outcome for Surveillance and Training

Improved Training Materials and Methods to Prevent Injuries and Illnesses

Mine safety and health professionals have long recognized training as a critical part of an effective safety and health program. Since 1977, federal regulations have required mine operators to provide safety and health training to all new miners, as well as a minimum of 8 hours of refresher training each year. Several major changes have taken place in the way mine safety and health training is conceived and practiced since 1977. We believe that our research has stimulated these changes. These include:

1. More emphasis on learning that requires collaboration and active problem-solving.
2. More integration of miners´ practical knowledge and experience with mandatory safety and health information they receive annually.
3. More realism in training scenarios and greater fidelity of visual illustrations.
4. Greater use of training materials that are thoroughly authenticated and field tested.

Our nation´s miners sit through millions of hours of mandatory safety and health training each year. Mining companies spend millions of dollars to provide this training. It is often unclear whether these miners are learning anything that can actually help them reduce their risk of occupational injury and illness. Many miners sit through the same training lectures and films year after year in order to fulfill the legal requirements. In these situations, their "training" ends up being an unfortunate waste of time and resources. However, when it is done well, training is valuable and worthwhile to both the miners and their employer.

With help from universities, mining companies, the Mine Safety and Health Administration (MSHA), and other providers of miners' training, NIOSH researchers have developed more than 80 training modules and products on a wide variety of safety and health topics. Most of these are intended to improve miners' ability to (1) recognize common workplace hazards or (2) handle nonroutine events such as fires and other types of mine emergencies. The main emphasis of the NIOSH Mining Program´s training research activity is not on producing training materials per se, but on finding better training processes and methods. Most of our training modules were developed during research studies to determine the feasibility and effectiveness of using innovative new methods to present occupational safety and health information to miners. These include computer simulations, interactive problem-solving stories, degraded stereoscopic (3-D) images of hazardous conditions, and videotaped interviews with miners.

According to MSHA records, NIOSH's mine training materials have been used extensively by the mining industry. During the past 20 years, trainers have obtained more than a half million copies through MSHA´s National Mine Health and Safety Academy. Numerous mining companies, mine trainers, and union officials have requested help from NIOSH mine training researchers. Several companies have provided financial support through Cooperative Research and Development Agreements. MSHA and state mining officials often request our help and advice on various matters related to miners´ safety and health training.

Intermediate Outcomes

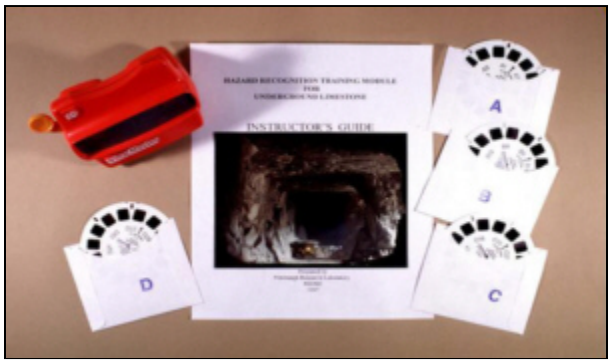
- 3-D Hazard Recognition Training: A New Approach to Preventing Injuries Associated With Construction, Maintenance and Repair Activities
- A Computer-based Training Simulation to Prevent Loss of Life During Mine Emergencies
- Interactive Problem Solving Stories: A New Approach to Preventing Miners' Occupational Injuries and Illnesses
- Mine Training Videos
- Western Train-the-Trainer (T3) Training Forum

Intermediate Outcome related to Improved Training Materials and Methods to Prevent Injuries and Illnesses

3-D Hazard Recognition Training: A New Approach to Preventing Injuries Associated With Construction, Maintenance and Repair Activities

Description of Problem

The U.S. aggregates and surface stone industry employs about 100,000 workers at 11,300 mine sites. Data collected during 1993-1997 showed that at least 40% of all injuries at these mining operations occurred during construction, maintenance and repair activities. It was determined that a training intervention was needed to ensure that surface miners are able to recognize and respond to the hazards linked with performing these types of activities.



Hazard recognition training materials

Research and Development Activities

An interactive training program was developed mainly for use with workers who perform construction, maintenance and repair work at surface mining operations, or the surface of underground mining operations. Trainees begin by viewing twenty 3-D images of various construction, maintenance and repair activities and workplace conditions. After viewing each slide, the instructor asks the trainees to list as many hazards as they can. They are then asked to explain what should be done to protect workers from these hazards. The instructor may also present additional information contained in the instructor's section of the training package. After viewing all of the slides, trainees are asked to take a 20-question true/false quiz. The instructor then leads a class discussion while reviewing the answers to the quiz.

The exercise addresses the following safety and health topics: confined space, electrical, ergonomics, excavation/trenching, falling materials, fire safety, general housekeeping, hand tools, hazard communication, health hazards, lockout/tagout, machine equipment guarding, material handling, mobile equipment, personal protective equipment, welding and cutting. This training exercise was developed in cooperation with aggregates mining companies and The Pennsylvania State University. It was authenticated with mine safety experts and extensively field tested with miners. The field test results suggest that this training leads to an increase in miners' knowledge. Those who took this training scored significantly higher on the 20-question true/false test than those who did not take the training.

R&D Outputs and Transfer Activities

The development and evaluation of this innovative training program has been the subject of several conference presentations and journal articles. Copies of this training program can be obtained from the Mine Safety and Health Administration's National Mine Health and Safety Academy. This training module can also be found by going to http://www.cdc.gov/niosh/mining/products/view-masterreeltrainingexercises.htm and clicking on "Hazard Rec. for CMR Activities" on the left.

Description of Intermediate Outcome

The training program has been very well received and widely adopted by those who train surface miners. Major aggregate producers, including Vulcan Materials and Hansen Aggregates, have incorporated the training into their Part 46 training classes. The program has been used at more than 1,500 mining operations throughout the United States. To date, more than 5,000 copies of the exercise have been requested. It is being used to train workers not only in the mining industry, but also in the construction, gas, and oil extraction industries. The Center to Protect Workers' Rights has recommended that it be used to train construction workers in many countries and has had it translated into Spanish. Copies of the program have been requested by trainers in 18 foreign countries.

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
Construction/Maintenance and Repair Activities: Hazard Recognition Training Program Rethi-LL; Flick-JP; Kowalski-KM; Calhoun-RA | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-158, 1999 Oct :3-79	1999	Publication	Surveillance and training
Development and Evaluation of a Training Exercise for Construction, Maintenance and Repair Work Activities Rethi-LL; Barrett-EA | In: Bockosh-GR, Karmis-M, Langton-J, McCarter-MK, Rowe-B eds. Proceedings of the Thirty-First Annual Institute on Mining Health, Safety and Research (Blacksburg, VA; Aug 27-30, 2000). Virginia Polytechnic Institute and State University, Department of Mining and Minerals Engineering; :93-102	2000	Publication	Surveillance and training
Out-of-the-Box Approach to Mine Safety: Focus on Construction, Maintenance, and Repair Activities Kowalski-Trakofler-KM; Rethi-LL | Professional Safety 48(1), 2003; :21-27	2003	Publication	Surveillance and training
Hazard Recognition Training Program for CMR Activities Rethi-LL; Flick-JP; Kowalski-KM; Calhoun-RA; Barrett-EA; Cornelius-KM; Haggerty-JJ; Saksena-N | NIOSH, 1999 Oct :1-78	1999	Training	All

Intermediate Outcome related to Improved Training Materials and Methods to Prevent Injuries and Illnesses

A Computer-based Training Simulation to Prevent Loss of Life During Mine Emergencies

Description of Problem

When emergencies start to unfold, it is critical that decision-makers respond quickly and effectively to prevent or minimize loss of life. Many people in the mining industry could potentially be thrust into the role of leading the response to an emergency. However, as mines become safer and major disasters fewer, the number of people who have had real experience in dealing with mine emergencies continues to dwindle. The industry needs a feasible and effective way to give future emergency command center leaders the opportunity to practice information gathering, situation assessment, decision-making, and coordination skills without risk to personnel or property.

Participating in a training session

Research and Development Activities

NIOSH scientists have developed a new training tool for potential emergency command center leaders. The Mine Emergency Response Interactive Training Simulation (MERITS) is an Internet-delivered, computer-based simulation exercise. It was developed to give trainees the experience of operating a command center during a major mine emergency. The exercise can be used in settings with limited resources available for larger-scale mock drills and can be used to train small numbers of individuals cost-effectively. The simulation setting is a small underground coal mine. Field tests have also found MERITS useful for training mine rescue teams and emergency response personnel at underground stone and surface mines.

R&D Outputs and Transfer Activities

MERITS was introduced to the general public in June 2002 via NIOSH *Technology News* No. 496. It was also introduced through several papers and presentations at mine safety conferences. MERITS can be downloaded from http://merits.niosh.cdc.gov/merits/. In the fall of 2003, the Pennsylvania Bureau of Deep Mine Safety adapted MERITS for its annual refresher training to rank-and-file miners and for its training course for new miners. The agency reports that these uses have been very effective. A key part of emergency response and rescue and of MERITS is effective communication. A supplemental training tool called "The Emergency Communication Triangle" was developed to address this need. NIOSH researchers were assisted by the state of Pennsylvania, the state of Colorado, the United Mine Workers of America, and various private mining companies in developing and field testing these training exercises.

Description of Intermediate Outcome

In his testimony before the U.S. Senate Appropriations Subcommittee on Labor, Health and Human Services, and Education, David E. Hess, Secretary, Pennsylvania Department of Environmental Protection, stated that training, including MERITS, was a key factor in the success of the Quecreek mine disaster response. He reported that "the rescued miners have said the safety training they received helped them in several ways, first to warn the other miners to leave the rapidly flooding mine, how to share resources and protect themselves underground and to understand what rescuers above ground would be doing to rescue them. Training includes live action sessions, workshops and MERITS." Along with supporting the use of MERITS, the Pennsylvania Bureau of Deep Mine Safety said in its Quecreek Mine Inundation Status Report/Action Plan that it would "make the 'emergency communication triangle' training module widely available." Copies of the simulation have been requested from safety and emergency response professionals in 28 states, the District of Columbia, and 19 foreign countries.

Outputs

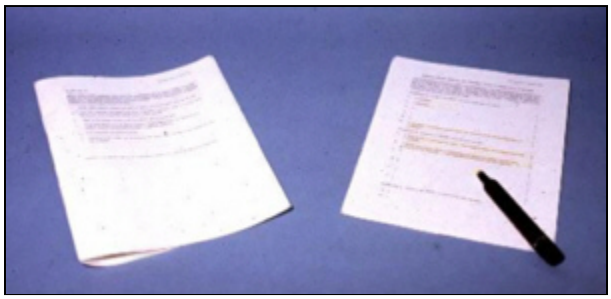
4 Outputs

Title	Year	Output Type	Strategic Goal
Emergency Response Command Center Training Using Computer Simulation Brnich-M; Mallett-L; Reinke-D; Vaught-C | In: 33rd Annual Institute on Mining Health, Safety, and Research Conference Proceedings, Roanoke, VA, August 11-13, 2002	2002	Publication	Mine disasters; Surveillance and training
Pennsylvania Incorporates Innovative Programs into Mine Rescue Training Eppley-D; Reinke-DC | MSHA Holmes Safety Association Bulletin, Feb/March 2002; :15-16	2002	Publication	Mine disasters; Surveillance and training
Technology News 496 - NIOSH Releases New Computer-Based Training Exercise Called MERITS Reinke-D; Mallett-L | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 496, 2002 June; :1-2	2002	Publication	Mine disasters; Surveillance and training
Mine Emergency Response Interactive Training Simulation (MERITS) NIOSH	2002	Training	Mine disasters; Surveillance and training

Intermediate Outcome related to Improved Training Materials and Methods to Prevent Injuries and Illnesses

Interactive Problem Solving Stories: A New Approach to Preventing Miners' Occupational Injuries and Illnesses

Description of Problem



Latent image training materials

The Federal Coal Mine Safety and Health Amendments Act of 1977 requires U.S. mine operators to provide formal safety and health training to all miners at least annually. The initial materials and methods used to conduct miners' training following passage of the 1977 Act were often found to be lacking in several ways. The training tended to be didactic, not interactive and engaging. Many instructors made no attempt to assess whether trainees remembered the information or were able to apply it. Trainees received little or no feedback. They only needed to be physically present in the classroom for a prescribed length of time.

Research and Development Activities

To help overcome these deficiencies, mine training experts at the NIOSH Pittsburgh Research Laboratory pioneered a new training method to improve miners' decision-making skills with respect to mine health and safety. The training is designed to teach judgment and decision-making skills within two broad domains: (1) how miners respond to mine emergencies (e.g., first aid, self-rescue, and escape) and (2) how miners integrate safety concepts within the context and performance of routine production work. The exercises are based on interviews and official reports of mine accidents, emergencies, and disasters. They reflect the problems and predicaments encountered by miners in these real-life events. Each problem-solving story is presented in a booklet as an unfolding story with a plot, characters, predicaments, goals, and obstacles. Trainees make a series of choices among good and bad action alternatives at critical decision points. Using a developing pen, they record their decision on a latent-image answer sheet and receive immediate feedback about the consequences of the action(s) they picked.

R&D Outputs and Transfer Activities

These exercises are available through the Mine Safety and Health Administration's (MSHA) National Mine Health and Safety Academy. They can also be viewed at http://www.cdc.gov/niosh/mining/products/invisibleinktrainingexercises.htm. MSHA is converting these simulations to a Web-based interactive format and is making them available through its website (http://www.msha.gov/interactivetraining.htm). These simulation exercises have also been the subject of several publications and presentations at mine safety conferences.

Description of Intermediate Outcome

The interactive problem-solving stories have been found to be very effective through field tests with thousands of miners. Mine trainers have purchased more than a half million copies of this type of training exercise. A detailed assessment of the use of our training simulations was published in NIOSH Information Circular (IC) 9459, "Use of Simulation Exercises for Safety Training in the U.S. Mining Industry". Researchers contacted 147 organizations that purchased the exercises from the National Mine Health and Safety Academy over a 2-year period. Feedback was obtained from 52 of these organizations. Sixty percent of the respondents rated the exercises as more useful than traditional instructional materials, 40% as equally useful, and 0% as less useful. Most trainers (79%) thought that the exercises helped them to make better use of workers' knowledge and experience during training. Fifty of the fifty-two respondents reported that they would like to have new simulations developed. Most showed an interest in helping to develop and field test new exercises. Ninety-four percent of the trainers judged the exercises as a good value; 92% planned to order more simulations in the future.

Outputs

63 Outputs

Title	Year	Output Type	Strategic Goal
Cripple Creek Deep Cut: An Exercise for Remote Control Miner Operators and Face Crews Steiner-LJ; Brnich-MJ; Duncan-J; Vaught-C; Calhoun-RA; Cornelius-KC; Rethi-LL; Rossi-EW; Turin-FC | National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-159, 1999 Oct :1-44	1999	Publication	Surveillance and training; Traumatic injuries
Decision Making During a Simulated Mine Fire Escape Cole-HP; Vaught-C; Wiehagen-WJ; Haley-JV; Brnich-MJ Jr. | IEEE Transactions on Engineering Management, 45(2), 1998; :153-162	1998	Publication	Mine disasters
Effective Hazard Recognition Training using a Latent-Image, Three-Dimensional Slide Simulation Exercise Barrett-EA; Kowalski-KM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 9527. NTIS stock number: PB95-170379, 1995; :36 pp	1995	Publication	All
I Can't Get Enough Air! Proper Self-contained Self-rescuer Usage Brnich-MJ; Vaught-C; Calhoun-RA | National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-160, 1999 Oct; :1-43	1999	Publication	Mine disasters; Surveillance and training
Investigation of a Slip/Fall Accident Rethi-LL; Wiehagen-WJ; Calhoun-RA; Garry-D; Cole-HP; Brnich-MJ | National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-156, 1999 Oct; :1-43	1999	Publication	Surveillance and training; Traumatic injuries
The Concept of Degraded Images Applied to Hazard Recognition Training in Mining for Reduction of Lost-Time Injuries Kowalski-Trakofler-KM; Barrett-EA | J Saf Res 2003; 34(5):515-525	2003	Publication	Surveillance and training
Use of Simulation Exercises for Safety Training in the U.S. Mining Industry Cole-HP; Wiehagen-WJ; Vaught-C; Mills-BS | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2001-141, Information Circular 9459, 2001 Sep; :1-20	2001	Publication	Cumulative injuries; Surveillance and training
Apparent Diving Accident University of Kentucky | USBM research contract H0348040, 1987 Jul; :1-30	1987	Training	Surveillance and training; Traumatic injuries
Basics of Transformers & Monitors West Virginia University; USBM | NIOSH, 1994 Dec	1994	Training	Surveillance and training; Traumatic injuries
Belt Fire Exercise University of Kentucky; USBM | USBM research contract H0348040; 1989 Jul	1989	Training	Mine disasters; Surveillance and training
Belt Fire Injury USBM | USBM, 1996 May	1996	Training	Mine disasters; Surveillance and training
Belt Haulage Accident University of Kentucky | USBM research contract H0348040; 1987 Aug	1987	Training	Surveillance and training; Traumatic injuries
Belt Line Problem University of Kentucky; State of Arizona | USBM research contract H0348040; 1988 Sep	1988	Training	Surveillance and training; Traumatic injuries

Title	Year	Output Type	Strategic Goal
Bennie's Chest Pain University of Kentucky | USBM contract H0348040, 1988 Jan; :1-25	1988	Training	Surveillance and training; Traumatic injuries
Bernie's Feeder Accident University of Kentucky | USBM research contract H0348040; 1988 May	1988	Training	Surveillance and training; Traumatic injuries
Bob's Electrical Shock University of Kentucky | USBM research contract H0348040; 1987 Aug; :31 pages	1987	Training	Surveillance and training; Traumatic injuries
Bob's Loader Accident Illinois Eastern Community College; University of Kentucky | USBM research contract H0348040; 1988 Oct	1988	Training	Surveillance and training; Traumatic injuries
Bulls Double Header: Too Much Unsupported Roof Kentucky Department of Mines and Minerals; USBM | USBM Purchase order P0325350; :35 pages	1994	Training	Ground control; Surveillance and training; Traumatic injuries
Cleo's Longwall Accident (invisible ink) University of Kentucky | USBM research contract H0348040; 1987 Nov	1987	Training	Surveillance and training; Traumatic injuries
Coal Miner's Chest X-ray Program University of Kentucky; USBM; West Virginia University | USBM 1997 Jul	1997	Training	Respiratory diseases; Surveillance and training
Continuous Miner Accident (invisible ink) University of Kentucky | USBM research contract H0348040; 1987 Aug	1987	Training	Surveillance and training; Traumatic injuries
Continuous Miner Fire Southwest Virginia Community College; University of Kentucky | USBM research contract H0348040; 1989 Jul	1989	Training	Mine disasters; Surveillance and training; Traumatic injuries
Cripple Creek Deep Cut Steiner-LJ; Brnich-MJ Jr; Vaught-C; Duncan-J | NIOSH, 1999 Oct :1-44	1999	Training	All
Cutthrough Ventilation Arrangement University of Kentucky | USBM research contract H0348040; 1987 Sep	1987	Training	Mine disasters; Surveillance and training
Delta Mine Cutthrough University of Kentucky | USBM research contract H0348040; 1988 Jun	1988	Training	Mine disasters; Surveillance and training
Drill Rig Incident Barrett-EA; Calhoun-RA | NIOSH Information Circular IC 9473; 2005 Feb; :1-19	2005	Training	Hearing loss; Surveillance and training
Electrical Shock Victim University of Kentucky; Polk Community College | USBM research contract H0348040; 1988 Apr	1988	Training	Surveillance and training; Traumatic injuries
Escape from a Mine Fire University of Kentucky; USBM | USBM research contract H0348040; 1989 Jun	1989	Training	Mine disasters; Surveillance and training
Haul Truck Repair Accident University of Kentucky | USBM research contract H0348040; 1987 Nov	1987	Training	Surveillance and training; Traumatic injuries

Title	Year	Output Type	Strategic Goal
Highwall Rescue Exercise University of Kentucky; Illinois Eastern Community Colleges | USBM research contract H0348040; 1989 Jul	1989	Training	Ground control; Surveillance and training; Traumatic injuries
I Can't Get Enough Air! - Proper Self-contained Self-rescuer Usage Brnich-MJ Jr; Vaught-C; Cahoun-RA | NIOSH 1999 Oct; :1-43	1999	Training	Mine disasters; Surveillance and training
Injury Rate Problem at Maxmore Mine University of Kentucky; USBM | USBM research contract H0348040; 1989 Jun	1989	Training	Surveillance and training; Traumatic injuries
Investigation of a Slip/Fall Accident Rethi-LL; Wiehagen-WJ; Calhoun-RA; Garry-D; Cole-HP; Brnich-MJ Jr | NIOSH 1999 Oct; :1-43	1999	Training	All
Leroy's Feeder Accident University of Kentucky | USBM research contract H0348040; 1988 Oct	1988	Training	Surveillance and training; Traumatic injuries
Lingering Smoke Exercise University of Kentucky | USBM research contract H0348040; 1987 Nov	1987	Training	Mine disasters; Surveillance and training
Low Coal Fire University of Kentucky | USBM research contract H0348040; 1987 Jul	1987	Training	Mine disasters; Surveillance and training
Main Haulage Scaling Exercise USBM | USBM 1996	1996	Training	Surveillance and training; Traumatic injuries
Man In the Bin University of Kentucky; Southwest Virginia Community College | USBM research contract H0348040; 1989 Jul	1989	Training	Surveillance and training; Traumatic injuries
Pete's Predicament: Unsupported Roof Kentucky Department of Mines and Minerals; USBM | USBM research contract H0348040; 1994 Oct	1994	Training	Ground control; Surveillance and training; Traumatic injuries
Pipe Repair Problem University of Kentucky; Southwest Virginia Community College | USBM research contract H0348040; 1989 Jun	1989	Training	Surveillance and training; Traumatic injuries
Pit Distribution Troubleshooting Illinois Eastern Community Colleges; University of Kentucky | USBM research contract H0348040; 1989 Jun	1989	Training	Surveillance and training; Traumatic injuries
Prep Plant Belt Problem University of Kentucky; Mountain Empire Community College | USBM research contract H0348040; 1989 Jul	1989	Training	Surveillance and training; Traumatic injuries
Problem in the Shop Illinois Eastern Community Colleges; University of Kentucky | USBM research contract H0348040; 1989 Aug	1989	Training	Surveillance and training; Traumatic injuries
Problem on Dragline #1 Illinois Eastern Community Colleges; University of Kentucky; Polk Community College | USBM research contract H0348040; 1989 Jul	1989	Training	Surveillance and training; Traumatic injuries
Problem on the Belt Line University of Kentucky | USBM research contract H0348040, 1987 Jul; :32 pages	1987	Training	Surveillance and training; Traumatic injuries

Title	Year	Output Type	Strategic Goal
Problem on the Catwalk (coal) University of Kentucky | USBM research contract H0348040; 1987 Nov	1987	Training	Surveillance and training; Traumatic injuries
Problem on the Catwalk (phosphate) University of Kentucky | USBM research contract H0348040; 1988 Jun	1988	Training	Surveillance and training; Traumatic injuries
Raggs & Curly Guarding Exercise USBM | USBM; 1995-01	1995	Training	Surveillance and training; Traumatic injuries
Roof Control at Intersections University of Kentucky | USBM research contract H0348040; 1987 Sep	1987	Training	Ground control; Surveillance and training; Traumatic injuries
Roof Fall Entrapment University of Kentucky | USBM research contract H0348040; 1987 Aug	1987	Training	Ground control; Surveillance and training
Roof Support in a Primary Escapeway USBM | USBM; 1990 Nov	1990	Training	Ground control; Surveillance and training
Sammy's Loose Roof Decisions USBM; University of Kentucky | USBM research contract H0348040; 1989 Jun	1989	Training	Ground control; Surveillance and training
Scoop Accident, First Aid Problem University of Kentucky | USBM research contract H0348040; 1988 Mar	1988	Training	Surveillance and training; Traumatic injuries
Smoke on the Section University of Kentucky | USBM research contract H0348040; 1987 Jul	1987	Training	Mine disasters; Surveillance and training
Tipple Heater Exercise Coal Mining Technology Illinois Eastern Community Colleges; University of Kentucky | USBM research contract H0348040; 1989 Jun	1989	Training	Surveillance and training; Traumatic injuries
Trailing Cable Electrical Problem West Virginia University; University of Kentucky | USBM research contract H0348040; 1990 Sep	1990	Training	Surveillance and training; Traumatic injuries
Trailing Cable Repair University of Kentucky | USBM research contract H0348040; 1987 Jul	1987	Training	Surveillance and training; Traumatic injuries
Traumatic Head Injury University of Kentucky | USBM research contract H0348040; 1987 Aug	1987	Training	Surveillance and training; Traumatic injuries
Travel Through Smoke USBM | USBM 1994 Sep	1994	Training	Mine disasters; Surveillance and training
Unsupported Roof Rescue University of Kentucky | USBM research contract H0348040; 1987 Jul	1987	Training	Ground control; Surveillance and training; Traumatic injuries
Vulcan Mine Ignition University of Kentucky | USBM research contract H0348040; 1987 Jul	1987	Training	Mine disasters; Surveillance and training

Title	Year	Output Type	Strategic Goal
Vulcan Mine Recovery University of Kentucky | USBM research contract H0348040; 1987 Sep	1987	Training	Mine disasters; Surveillance and training; Traumatic injuries
Water Line Repair University of Kentucky | USBM research contract H0348040; 1987 Jul	1987	Training	Surveillance and training; Traumatic injuries

Intermediate Outcome related to Improved Training Materials and Methods to Prevent Injuries and Illnesses

Mine Training Videos

Description of Problem

Video poster

The need for effective training materials was identified to the NIOSH Spokane Research Laboratory (SRL) during a series of stakeholder meetings held throughout the West. Safety trainers reported that good-quality training tools specific to mining topics were either missing altogether or were too outdated to be of any use. In addition, annual refresher training was not viewed positively by miners. They resented having "nonminers" tell them how to do their jobs and were resistant to any safety messages delivered by people who didn't look and talk like miners. SRL worked with mine safety trainers in various segments of the industry, as well as with the Mine Safety and Health Administration (MSHA) and mining associations, to develop a list of topics that was perceived as critical needs and to begin filling the gaps in effective safety training materials.

Research and Development Activities

SRL has created a library of 10 mine safety and health training videos during 1999-2004. (Some titles are also available in DVD format.) The videos cover topics identified as needed by safety professionals from a range of mining sectors. These include handling explosives, installing ground supports, avoiding rock falls, working safely around highwalls or surface prep plants, and the long-term effects on workers impacted by disaster and tragedy at the workplace. The videos contain real miners working in real mines to bring their safety messages to life. In addition, they capture and hold the interest of miners by using stories to engage trainees. The videos were developed collaboratively with safety professionals working in the topic area with the full cooperation of mining operations. MSHA and the International Society of Mine Safety Professionals (ISMSP) were active partners in developing these materials. The videos have proven to be highly effective in transferring information to miners, who respond favorably to people they consider to be "master miners" acting as mentors.

R&D Outputs and Transfer Activities

The videos are continuously in demand. To date, about 12,000 of them have been shipped to mine safety and health trainers in more than 36 countries. (Videos are provided only upon demand. Every requestor is entered into a customer database to allow followup and to obtain user feedback information.)

Thirteen articles and papers have been published by SRL on this work since 2000. Two reports have been prepared by outside researchers under contract to evaluate the effectiveness of the videos as training tools. A total of 35 presentations have been given at national and international conferences since 2002. In addition, a 90-minute workshop on this research is scheduled for the National Safety Council/World Safety Congress in September 2005.

Description of Intermediate Outcome

The SRL training videos are widely used in the U.S. mining industry. Mining companies, MSHA, mining associations, and state agencies have all provided money or in-kind services so that the videos could be produced. However, the use of these training products has expanded beyond the mine site. Industries as diverse as insurance, tunnel building and construction, the military, and even university occupational safety and health programs have begun to use them in their training programs. They are held in such high regard that safety trainers have requested additional copies after their originals are kept by members of their training audiences.

The work has been recognized by safety and training professionals outside the U.S. mining industry as well. Five journal and media articles (written by others) have appeared in the past 3 years. These include:

- Smith S [2005]. Preaching or teaching: the use of narrative in safety training. Occup Hazards, April 13.
- Naso M [2005]. Tell me a story: how experience and people help teach safety. Saf Health Magazine. National Safety Council, May.
- SafetyWA Magazine [2003]. Workers are the stars. West Australia J Occup Saf Health, December.
- The Australian Mining Times [2003]. Storytelling as a safety tool. October.
- Kral S [2003]. Improved training reduces worker injuries. Min Eng, October.

The NIOSH videos have been recognized for their outstanding contribution to safety and health training and have earned several national awards. These include the NIOSH top honors for Educational Materials (Alice Hamilton Awards) in 2000 and 2001, CDC's Communicators' Roundtable Award for Electronic Media in 2002, a Guiding Light award from ISMSP in 2002, the ISMSP Highest Degree of Safety Award in 2000, and a Telly award (given to broadcast media such as TV, cable, and satellite programming) in 2003. Two of the videos have also been accepted for the International Film Festival competition held during the 2005 World Congress on Safety and Health at Work.

Outputs

23 Outputs

Title	Year	Output Type	Strategic Goal
Development of NIOSH Hard-Rock Safety Training Materials Cullen-ET | Presentation at 108th annual exhibit and meeting, Society for Mining, Metallurgy, and Exploration, Denver, CO, Feb. 26-28, 2001; :4 pp	2001	Publication	Surveillance and training
Feeding the Multitudes - How to Connect With Customers Cullen-ET | Presentation at 108th annual exhibit and meeting, Society for Mining, Metallurgy, and Exploration, Denver, CO, Feb. 26-28, 2001; :6 pp	2001	Publication	Surveillance and training
Getting to Zero-The Human Side of Mining Cullen-ET; Camm-TW; Jenkins-FM; Mallett-L | U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupatoinal Safety and Health, Spokane Research Laboratory, Spokane, WA, DHHS (NIOSH) Publication No. 2006-112, Information Circular # 9484, November, 2005; :1-32	2005	Publication	Surveillance and training
Mine Safety Training: Past, Present, and Future Cullen-E | Minesafe International 2000 (Perth, Australia, Sept. 3-8, 2000). Chamber of Minerals and Energy of Western Australia, Perth, Australia, 2000 Sep; :151-154	2000	Publication	Surveillance and training
Releasing the Energy of Workers to Create a Safer Workplace: The Value of Using Mentors to Enhance Safety Training Camm-TW; Cullen-ET; | In: Peters R, ed. Strategies for Improving Miners' Training. Pittsburgh, PA, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Information Circular 9463, 2002 Sep :35-38	2002	Publication	Surveillance and training
Teaching Miners: Breaking the Barriers to Learning Cullen-E | Minesafe International 2003. Perth, Western Australia: The Chamber of Minerals and Energy of Western Australia, Inc., 2003 Oct; :1-8	2003	Publication	Surveillance and training
Technology News 482 - Ground Support Safety Training Video NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 482, 2000 Jul :1-2	2000	Publication	Ground control; Surveillance and training
Technology News 491 - NIOSH Releases Two New Safety Training Videos NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 491, 2001 Jun :1-2	2001	Publication	Surveillance and training
Technology News 494 - Expert Miner Training Video Released by NIOSH NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 494, 2002 Mar :1-2	2002	Publication	Surveillance and training
Technology News 497 - "You Are My Sunshine": A New Video Release From NIOSH on the Sunshine Mine Fire NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 497, 2002 Aug; :1-2	2002	Publication	Mine disasters; Surveillance and training

Title	Year	Output Type	Strategic Goal
Technology News 502 - New Training Video for Aggregate Operators: Aggregate Training for the Safety Impaired Cullen-E | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 502, January 2003	2003	Publication	Surveillance and training; Traumatic injuries
Tell Me a Story: Why Stories are Essential to Effective Safety Training Cullen-ET | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Pub. No. 2005-152, Report of Investigations 9664	2005	Publication	Surveillance and training
Tell Me a Story: Using Narrative to Teach Safety to Skilled Blue-Collar Workers Cullen-E | In: Proceedings, Risk and Safety Management in Industry, Logistics, Transport, and Military Service: New Solutions for the 21st Century. London: U.S. Navy, Office Of Naval Research, International Field Office, 2003 Mar; :1-4	2003	Publication	Surveillance and training
Aggregate Training for the Safety Impaired Cullen-ET | NIOSH 2003 Dec; :Video (VHS format, 35 minutes)	2003	Video	Surveillance and training; Traumatic injuries
Aggregate Training for the Safety Impaired, Spanish version Cullen-ET | NIOSH 2003; :Video (VHS format, 35 minutes)	2003	Video	Surveillance and training; Traumatic injuries
Handling Explosives in Underground Mines Cullen-ET | NIOSH 1998 Jan; :Video (VHS format, 15 minutes)	1998	Video	Surveillance and training; Traumatic injuries
Hazards In Motion Cullen-ET | NIOSH 2001; :Video (VHS format, 30 minutes)	2001	Video	Surveillance and training; Traumatic injuries
Hidden Scars Cullen-ET | NIOSH 2001 Jan; :Video (VHS format, 25 minutes)	2001	Video	Ground control; Traumatic injuries
Miner Mike Saves the Day! or Ground Support... It's Important! Cullen-ET | NIOSH 2000 Jan; :Video (VHS format, 33 minutes)	2000	Video	Ground control; Surveillance and training
Rock Falls - Preventing Rock Fall Injuries in Underground Mines Miller-A | NIOSH 1999 Jan; :Video (VHS format, 20 minutes)	1999	Video	Ground control
The Sky Is Falling Cullen-ET | NIOSH 2004 Aug; :Video (VHS format, 38 minutes)	2004	Video	Ground control; Surveillance and training; Traumatic injuries
You Are My Sunshine Cullen-ET | NIOSH 2002 :Video (VHS format, 69 minutes)	2002	Video	Mine disasters
Zen and the Art of Rockbolting Cullen-ET | NIOSH 2002 Jan; :Video (VHS format, 33 minutes)	2002	Video	Ground control

Intermediate Outcome related to Improved Training Materials and Methods to Prevent Injuries and Illnesses

Western Train-the-Trainer (T3) Training Forum

Description of Problem

A series of focus group meetings were held with members of the minerals industry beginning in 1998 and continued at several Critical Issues conferences sponsored by the International Society for Mine Safety Professionals (ISMSP). Through these meetings, the Spokane Research Laboratory (SRL) became aware of the need for a western version of the Mine Safety and Health Administration's (MSHA) popular TRAM (Training Resources Applied to Mining) mine safety training program held annually to train trainers in Beckley, WV. Trainers in the Western United States did not believe they had a forum where they could gather, share ideas and best practices, and find solutions to safety problems. Because of the geographical and economic barriers preventing western safety trainers from attending the TRAM Conference in Beckley, few of the western trainers got involved. Most felt isolated from their peers and from new, innovative training methods and materials. The western trainers believed that the miners for which they were responsible were being impacted by this lack of access to each other and the collective wisdom they had to share. SRL researchers began working with industry and government partners to remedy the situation.

Research and Development Activities

The first Western TRAM Conference was held in Reno, NV, in June 2003. SRL took advantage of the planned meeting of the Joseph A. Holmes Association, a nonprofit, safety-oriented organization supported by MSHA, but not a well-known entity in the West, and added a "train-the-trainer" forum to it. The list generated from the database of customers of SRL's training videos was used to contact safety trainers in the West and to invite them to attend the first-ever western conference specifically for safety trainers. A total of 340 mine safety and health experts from both industry and government participated. More than 50 safety professionals from government and industry provided practical training programs and materials. Feedback was very positive, and there was an immediate demand by safety and health trainers to make this an annual event. Since that time, SRL has organized and coordinated the western equivalent of TRAM. It is called Train-the-Trainer (T^3) and has provided more than a dozen presenters to augment the list of topics available to attendees. In 2004, T^3 was held in Salt Lake City, UT, in conjunction with the conference of the Institute on Mining Health, Safety and Research and the ISMSP Critical Issues Conference. It drew more than 400 safety and health trainers from the United States, Canada, Mexico, Venezuela, United Kingdom, Australia, and other countries. This has become an annual event.

R&D Outputs and Transfer Activities

The T^3 conference is an excellent opportunity for NIOSH to share the materials and information it has developed with western safety trainers. These trainers will take the information directly to miners and discover the major concerns and issues in the mine safety arena. Thirty-one researchers from SRL and the Pittsburgh Research Laboratory (PRL) have presented their work at T^3, covering a wide variety of topics. Of particular interest has been the work done at both SRL and PRL on developing training materials for coal and metal/nonmetal mining. The exposure to safety professionals provided by the conference has greatly expanded the potential customer base for both labs.

Description of Intermediate Outcome

NIOSH has played a major role in organizing three international train-the-trainer conferences in the Western United States. The T^3 conferences have become the largest gathering of mine safety professionals in the West. They offer trainers the opportunity to meet and share ideas and solutions. Without NIOSH's efforts to create and organize T^3, western safety trainers would not have access to NIOSH training materials or the collective wisdom of their peers. Agency researchers have benefited from the opportunity to work with several hundred safety and health specialists from many countries, representing a wide array of expertise and topical knowledge. The T^3 conference provides an invaluable opportunity to trainers. It also leads to recognition of agency research, visibility for its researchers, expanded contacts in the industry for future collaborative efforts, and an opportunity to provide training materials and methods to hundreds of trainers in the mining industry. These trainers, in turn, can now provide the benefits of these better practices to much of the western U.S. mining workforce.

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
Coaching Skills for On-the-Job Trainers Mallett-LG; Kowalski-Trakofler-K, Vaught-C; Wiehagen-WJ; Peters-RH; Keating-P | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-146, Information Circular 9479	2005	Publication	Surveillance and training
2003 Western TRAM Conference NIOSH | Held jointly with the Joseph A. Holmes Safety Association meeting (Reno, NV; June 2003)	2003	Workshop, Seminar, or OIB	Surveillance and training
2004 Train-the-Trainer (T3) Conference NIOSH | Held jointly with the Institute on Mining Health, Safety and Research meeting and ISMSP's Critical Issues Conference (Salt Lake City, UT; May 2004)	2004	Workshop, Seminar, or OIB	Surveillance and training
2005 Train-the-Trainer (T3) Conference NIOSH | Held jointly with the ISMSP's Critical Issues Conference (Reno, NV; May 2005)	2005	Workshop, Seminar, or OIB	Surveillance and training

Strategic Program Outcome for Surveillance and Training

Reducing the Hazards of Mining's Emerging Issues

Emerging issues in miner health are driven by deeper and more complex mines; shifting work organization; changing airborne particles from advancing technologies; bigger, faster, and more sophisticated machinery; and new chemical exposures. Miners and emergency responders face extreme heat and cold stresses as mines become more remote or go deeper. Increasingly complex mines challenge miners´ ability to navigate through everyday work processes but more critically, under emergency situations. Miners are exposed to chemicals, metals, and trace toxic substances that continue to evolve due to technological or environmental changes. Improving health outcomes will require both the use of emerging technologies to solve health hazards as well as attention to the hazards introduced by new technologies.

A specific example of an emerging health issue is mine workers´ exposures to chemicals, dusts, mine gases, and industrial fumes. Overexposure to these substances may cause acute or chronic health problems. A NIOSH study inventoried 2,570 different chemical substances and 84,939 trade name substances at 491 selected mine sites. The results show potential exposures to a variety of chemical hazards in U.S. mines. The effects of these chemical and environmental hazards are hard to quantify. Traditional occupational health surveillance data, such as those from the Bureau of Labor Statistics, significantly underestimate injuries and illnesses, and special filters must be used to supplement the numbers. The Mine Safety and Health Administration also requires injury, illness, and disease documentation, but only those that are most obviously work-related may actually be reported. For instance, because most diseases take time to become symptomatic, the ability to directly link the disease to work exposure is reduced.

The health hazards emphasis is relatively new for the NIOSH mining program compared with other programs that have a longer history and a record of impressive influence on the industry. Potential outcomes of the health hazards program are expected to improve the health and safety of miners. However, there are specific outcomes in the intermediate stage that are already beginning to influence the reduction of chemical and environmental exposures.

- The HazCom Helper software program provided an enhanced communication tool for mine companies, thus raising awareness of chemical hazards in the workplace beyond minimal compliance requirements.
- Mine rescue teams are more aware of and are using procedures such as forced rest and body temperature monitoring to maintain optimum activity levels while working in hot environments.

The transfer of key findings has occurred in conferences among scientific peers and at seminars and workshops for mining safety and health professionals, as well as through publications, CDs, and other products.

Intermediate Outcomes

- Reducing Hazards through Better Communications
- Reducing Heat Strain Health Hazards

Intermediate Outcome related to Reducing the Hazards of Mining's Emerging Issues

Reducing Hazards through Better Communications

Description of Problem

In 2002, the Mine Safety and Health Administration (MSHA) enacted a new regulation-30 CFR 47 (HazCom rule). This requires all mines to develop a written hazard communication program that includes tracking hazardous chemicals at their sites. All mines with six or more workers were to comply by September 23, 2002; those with fewer than five workers were to comply by March 21, 2003. NIOSH personnel met with representatives from several mining companies and MSHA administrators to discuss what NIOSH could do to help small- to medium-sized mines that lack the resources to successfully comply with the MSHA HazCom rule. NIOSH determined that companies would need assistance with writing the required HazCom plan and developing a list of all hazardous chemicals at their mine.

Following many requests for the HazCom Helper from companies regulated by OSHA, NIOSH revised the program to create the HazCom Helper-OSHA version to be more compatible with the specific needs of these nonmining companies.

Research and Development Activities

To meet this need, NIOSH developed the HazCom Helper to assist individuals in writing a HazCom plan in a step-by-step fashion. The NIOSH HazCom Helper is approved by both MSHA and OSHA and can be downloaded from the NIOSH Web site at (http://www.cdc.gov/niosh/mining/topics/chemicalhazards). Both MSHA and OSHA inspectors accept the HazCom Helper written plan as complying with their respective HazCom rules.

R&D Outputs and Transfer Activities

Mining companies, MSHA, training consultants, and universities have requested more than 3,600 copies of the HazCom Helper. The product was the second most downloaded software from NIOSH's Web site in 2003 and 2004. In an effort to raise awareness of the hazardous chemicals to which miners are exposed, the mining program also developed hands-on workshops ("A Layman's Guide to HazCom Compliance") and seminars ("Overview of Hazards and Controls associated with Common Chemicals Found in Mining"). These were presented at six locations throughout the United States during 2003-2004. Also, MSHA requested that a workshop be held to explain the use of the HazCom Helper at the 22nd Annual South Central

Joint Mine Health and Safety Conference in Albuquerque, NM (March 2004). MSHA trainers use the HazCom Helper in regional workshops for miner training and as a training tool at its inspector training facility. More than 1,000 CD versions of the HazCom Helper have been used in MSHA-hosted training seminars and workshops.

Description of Intermediate Outcome

This project has helped both the mining community and nonmining companies by providing a tool that (1) aids in reducing the administrative burden of preparing a written HazCom plan, (2) improves the quality of information in the HazCom plan, and (3) increases worker awareness of hazardous chemicals in the workplace. Testimonials from returned evaluations include the following: "Good product! We had a program, but used it [HazCom Helper] to enhance what we already had."; "Very useful and beneficial to operators!"; "I am glad I found your program; it has made this step much easier for me!"; and, "I have looked at the NIOSH HazCom helper. It is slick and helpful for the in-plant hazard communication program, especially for small businesses."

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
Technology News 503 - HAZCOM Helper: Compliance Tool for MSHA Rule 30 CFR Part 47 Scott-D; Drake-P | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 503, 2003 Mar; :1-2	2003	Publication	Surveillance and training
Technology News 510 - HazCom Helper - OSHA Version: Compliance Tool For OSHA Rule 29 CFR 1910.1200 NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 510, 2005 Oct; :1-2	2005	Publication	Surveillance and training
HazCom Helper - MSHA Version Scott-DF; Drake-PL; Brady-TM | NIOSH Pub. No. 2003-18. 2003; CD-ROM	2004	Software	Surveillance and training
HazCom Helper - OSHA Version Scott-DF; Drake-PL; Brady-TM | NIOSH Pub. No. 2003-18. 2003; CD-ROM	2005	Software	Surveillance and training

Intermediate Outcome related to Reducing the Hazards of Mining's Emerging Issues

Reducing Heat Strain Health Hazards

Description of Problem

In October 2002, two mine rescuers died from heat exposure during training exercises in an underground gold mine. Deep underground metal mines experience extreme environmental conditions due to the thermal gradient of the rock at depth and the contribution of heat from diesel powered equipment. During mine emergencies there is the potential of additional heat load from a fire while ventilation systems used to remove this heat burden could be compromised.

Research and Development Activities

Research conducted under conditions similar to those of the October 2002 accident identified pre-rescue-activity body temperature as a significant predictor of an individual's tolerance for heat exposure during the activity. The use of pre-rescue-activity body temperature to identify at-risk individuals in mine rescue activities would reduce the risk to the individual and the team mission due to failure of an individual to perform. The research also identified a forced-rest regimen based on resting heart rate that can greatly reduce the risk of heat strain-related injuries by limiting the metabolic heat load. The research identified the need to limit work-rest regimens beyond the recommendations of the current NIOSH Recommended Standard in order to protect this special class of worker.

R&D Outputs and Transfer Activities

Study findings were published in the 2005 Transactions of the Society for Mining, Metallurgy, and Exploration, Inc. Three presentations were given targeting a range of audiences, including mining professionals and mine safety trainers. One of these was at the 2005 Mines and Aggregates Safety and Health Association (MASHA) safety conference in Ontario, Canada.

Description of Intermediate Outcome

The results from monitoring core temperatures and heart rate of mine rescue teams during underground training exercises led 16 US and Canadian mine rescue teams who work in hot environments to alter their procedures. These teams now pre-screen participants for baseline body temperatures in order to identify individuals at high risk of injury from working in a hot

environment. In addition, eight teams have altered their procedures to provide adequate rest periods during mine rescue activities. This outcome is continuing to gain acceptance in the affected parts of the mining industry, as evidenced by requests for information on the application of the methods in Australia and the United Kingdom.

Outputs

1 Output

Title	Year	Output Type	Strategic Goal
A Study of Heat Stress Exposures and Interventions for Mine Rescue Workers Varley-F | Trans Soc Min Metal Explor 2004 Dec; 316:133-142	2004	Publication	Surveillance and training